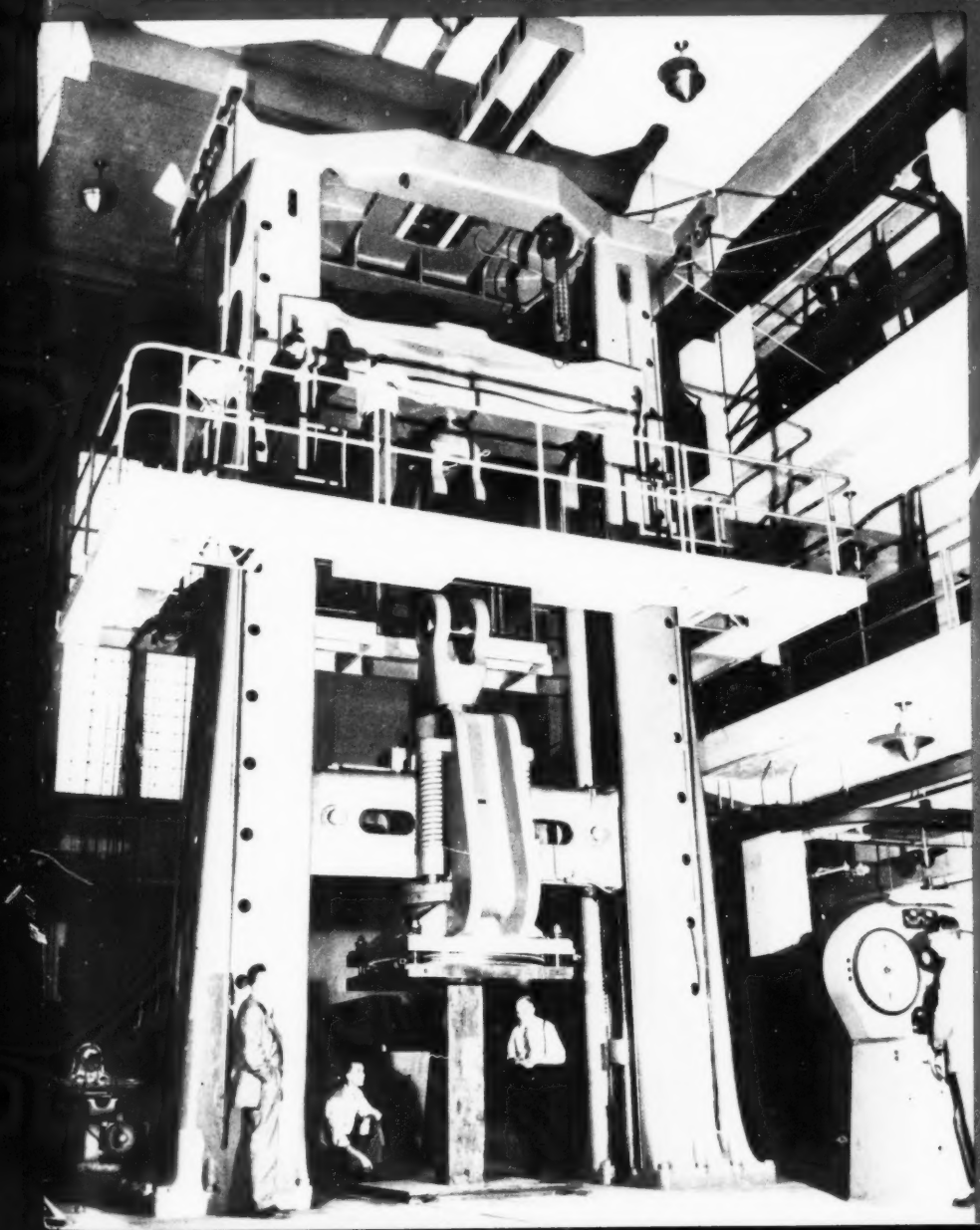
The TREND IN ENGINEERING

At the University of Washington



In this issue:

- The Experiment Station Expands
- Heat Pump for Residential Heating
- Supersonic Wind Tunnels
- Radio Wave Survey in Seattle
- The New Tacoma Narrows Bridge
- The Electron Microscope

December, 1948

VOL. 1, No. 1

Advertising space will be available in future issues of *The Trend in Engineering* at the University of Washington. Inquiries should be addressed to the Editorial Associate, Engineering Experiment Station, University of Washington, Seattle 5.

THE Engineering Experiment Station of the University of Washington was established in December, 1917, to co-ordinate investigations in progress and to facilitate the development of engineering and industrial research in the University. Its purpose is to aid in the industrial development of the state and nation by scientific research and by furnishing information for the solution of engineering problems.

The scope of the work is three-fold:

(1) to investigate and publish information concerning engineering problems of a more or less general nature that would be helpful in municipal, rural, and industrial affairs;

(2) to undertake extended research and to publish reports on engineering and scientific problems;

(3) to provide opportunities for graduate engineers to conduct research under conditions that will most effectively prepare them for professional service.

For administrative purposes the work of the Station is organized into nine divisions:

1. Aeronautical Engineering
2. Chemical Engineering, Industrial Chemistry
3. Civil Engineering
4. Electrical Engineering
5. Forest Products
6. Geology
7. Mechanical Engineering
8. Mining, Metallurgy, Ceramics
9. Physics Standards and Tests

The control of the Station is vested in a Station Board consisting of the President of the University, the Dean of the College of Engineering as chairman, the Director of the Station, and members of the faculty, representative of the administrative divisions. The Board determines the character of the investigations to be undertaken and supervises the work.

The Station offers a substantial number of research fellowships to highly qualified graduate students who work under the direct supervision of the faculty of the various divisions. The results of the investigations are published in the form of bulletins, technical notes, and reports. Reprints of articles by members of the engineering faculty and graduate students published in recognized technical journals are also issued by the Station. Requests for copies of the publications and inquiries for information on engineering and industrial problems should be addressed to the Director, Engineering Experiment Station, University of Washington, Seattle 5.

December, 1948

The TREND IN ENGINEERING

at the University of Washington

Vol. 1 No. 1

Published by the Engineering Experiment Station at the University of Washington to reflect the current highlights of its accomplishments and to report progress in its program of investigation and research.

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COVER

Structural testing machine at the Engineering Experiment Station. Maximum capacity in tension or compression: 2,400,000 lb.

The Experiment Station Exhibit at the Labor-Industry Exposition Drew Interested Crowds. *(See page 23.)*

Photo by DeWayne Sharp 1948

THE ENGINEERING EXPERIMENT STATION EXPANDS

F. B. Farquharson

Director, Engineering Experiment Station

F. B. Farquharson

During the past three years the Engineering Experiment Station has expanded its activities to such an extent that today it is scarcely recognizable in comparison with its small beginning of thirty-one years ago. This growth is evident in a budget increase of some sixty-six times that of the average of the first three decades and a staff expansion from practically zero to the equivalent of twenty-two full-time employees, in addition to forty-five research fellows at work. The Station is now, in fact, a going concern.

At this stage, the realization of a long standing ambition in this first issue of a new publication brings further gratification. *The Trend in Engineering* as it appears at the University of Washington is dedicated not only to furthering the progress of engineering investigation and research, but particularly to increasing the University's influence on the industrial development of the state and nation and providing opportunities for contacts between graduate engineering students and the industrial world. For the present it will appear quarterly, but the Station has its sights fixed on a distant star which may lead to a more frequent appearance as conditions warrant.

In keeping with modern trends as well as in an effort to meet the sharply rising cost of production, this new publication will appear in offset form, as will, indeed, all other future publications of the Station. The recent acquisition of the latest model of electric typewriter with proportional bookface type and marginal justifier will permit preparation of copy in the Station's own offices up to the final process of lithoprinting. Part ownership in a Varityper will also provide a wider flexibility in type style and afford satisfactory reproduction of the most complex mathematical forms. The change in format, therefore, should not entail any sacrifice in utility or elegance.

A brief review of the history of the Engineering Experiment Station in this issue seems relevant in order that the steps by which its complete transformation has been accomplished may be clearly seen.

From the date of its founding in 1917 until early 1945 the Engineering Experiment Station devoted its efforts to the encouragement of research in the various divisions of engineering, but, because its finances were always extremely limited, the stimulation rarely went beyond publication facilities.

In 1945 this picture was considerably altered by a grant from the State which made it possible to subsidize twenty graduate students in work towards a Master's degree. The total grant was sufficient to keep ten graduate students at work each of two years and to provide, in addition, an average of $200.00 per student for laboratory expenses.

The turbulent period which followed immediately after the war made it exceedingly difficult to obtain qualified graduate students, but the net result of the expenditure of this grant was very encouraging and several publications in national magazines resulted.

The two-year experimental period just described opened up a broad vista of possibilities for a complete change in the complexion of the Engineering Experiment Station and resulted in budget requests before the 1947 Legislature very much in excess of the modest sums previously requested.

In the course of preparing this enlarged budget request, a series of long discussions took place which led to the establishment of a broad and somewhat unusual philosophy covering the relationship between the work of the Engineering Experiment Station and the general academic mission of the College of Engineering.

It was agreed that, although the importance of purely theoretical research should not be minimized, the general effectiveness of modern engineering teaching is clearly influenced by the experience and attitude of the teacher in his relationship to the demands and needs of industry, and, hence, that an engineering faculty, with few exceptions, should not be removed from contacts with industry to any "splendid isolation of the academic ivory tower."

A further conclusion was that the mere fact of some early contact with industry was not in itself a sufficient guarantee of a teacher's realistic approach to the problems of advanced engineering education, but, rather, that to be truly successful he must keep abreast of modern engineering trends through constant touch with some aspect of current industrial problems. This contact might be maintained either through consulting, or co-operative research, or both.

The approach to this whole problem, which has been increasingly under discussion in recent years, seems to be in a well integrated engineering research program, which should give (1) contacts with industrial problems in such sponsored projects as do not conflict with the restrictions of university participation, (2) contacts with specialists in different fields through departmental co-operation, (3) experience in research teamwork. In promoting such a program, the engineering experiment station's function in the first two parts is obvious.

It should act as a liaison with industry and as a co-ordinator between departments, leaving the individual departments free to plan and carry out the actual projects.

The rapid development of industrial research in recent years is responsible for a significant change in industry's idea of good preparation for a career in that field. Not so long ago it pleaded with the universities not to "spoil" their men by over-training, but "to give them the fundamentals and let us break them into our own ways." Today, though emphasis is still laid on more thorough basic training, with less time devoted to highly specialized courses, a new note is heard.

A. E. Buchanan, of the E. I. DuPont de Nemours Company asserts,* "We need in our businesses a new kind of engineer, one with a distinct professional stature, one which we think the Universities have not previously or generally produced for us-- the research engineer," and goes on to say, further, "I think it is safe to say that industry would welcome postgraduates from those universities which devise advanced training especially appropriate for research engineers. I am sure that we would encourage our good 4-year men to return to the universities for this type of advanced education."

Such advanced training evidently must be found in a research program which provides for co-operation with industry and thereby permits participants to learn at first hand some of the angles of the industrial approach. Its benefits, moreover, would affect not only students planning a career in industrial research, but those intending to work in purely theoretical or general fields.

To execute its part in such a program, then, has been the goal of the Engineering Experiment Station since entering on its expanded program.

The first steps were taken when the 1945 Legislature by special bill provided $24,000 to be used, as previously mentioned, to finance twenty graduate research fellowships during the 1945-47 biennium. By means of this grant in addition to the usual allocation of funds from the university budget, the Station was enabled to set up a preliminary plan for its extended activities. The generous postwar development in the building of laboratories and the addition of equipment which also started at this time gave further encouragement. As a result, a much increased budget was prepared for the 1947-49 biennium which made possible a vast acceleration of the program. During the first year, in spite of the tight postwar market in graduate students, an average of forty-nine out of a contemplated sixty research fellows were engaged on forty-eight projects.

The supervision of these projects required the hiring of nine full-time men classified variously as research associates and research assistants, and two part-time, in the same classifications. This total number was raised to eleven and one-half the second year.

The fact that the number of fellows available during the first year of the biennium was below the original estimate of sixty, made it possible to increase the total number of machinists and mechanics to four machinists and two full-time and four part-time mechanics, as well as to provide, in the second year, the additional supervision assistance noted above, as the research program in certain departments was more fully developed. The publication program of the Station, too, is taking on such proportions that a full-time editorial associate has been hired for the second year, as well as necessary additions to the clerical staff.

A fairly large allocation from the amount set aside in the operations budget for new equipment has permitted the acquisition of a number of major items of equipment of use in more than one field of research and, in the case of the most expensive item, the electron microscope, for the use of the whole University. Other equipment includes a weatherometer, radio-frequency standard, ultraviolet spectrophotometer, Tukon hardness tester, and acoustical equipment.

The research projects now under way are fairly well distributed. At present the Electrical Engineering Department is represented by five projects; Mechanical Engineering, by four; Chemical Engineering, by twelve; Civil Engineering, by ten; Aeronautical Engineering, by five; Forestry, by six; Physics, by two; and Geology and Metallurgy, by one each. In addition, two projects are under the direct control of the Director.

In the three years of its expanded program, the Engineering Experiment Station has made a modest beginning toward promoting a closer relationship with local and regional industries and with state and federal organizations. During this period a total of approximately $30,000 was obtained from such sources in addition to the amount granted by the Legislature.

The newly appointed Assistant Director of the Station is acting as special liaison officer in this direction to stimulate the interest and participation of industries in the research program and to point out special equipment available in the Station laboratories for their use. Other organizations, such as the Bonneville Power Administration, the Washington Toll Bridge Authority, and the Public Roads Administration are already working in co-operation with the Station.

The addition of the major items of equipment already described, together with extensive facilities previously available for research in the various laboratories, has greatly improved the University's opportunity to accomplish a well rounded program of graduate study and research in which both the faculty and students participate to mutual advantage.

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*A. E. Buchanan, "Industry's Requirements for Research Graduates," *Journal of Engineering Education*, Vol. 38, No. 8 (April, 1948).

THE HEAT PUMP FOR RESIDENTIAL HEATING

G. W. Smith
Professor of Electrical Engineering

ECONOMICS AND OPERATING CHARACTERISTICS*

Introduction. The steadily increasing cost of oil and coal as fuels for residential heating, together with the public's desire for a cleaner and more convenient means of heating, has directed attention to the use of refrigerant equipment as a heat pump and suggested the extensive investigation sponsored by the Engineering Experiment Station aided by the Bonneville Power Administration. This research, under the direct supervision of the writer, in the Department of Electrical Engineering, is being carried on with the assistance of one or more research fellows including, from its inception up to the present time, Harvey Christensen (1946-47), Arthur Presson (1946-47), Lawrence L. Giller (1947-48), and Louis C. Sutherland (1947-).

Method of Study. Since sufficient data were not available to determine the maximum first cost of heat-pump installation which would permit competition with conventional forms of electric heating, the problem was approached by determining comparative operating costs. Thus, if the operating cost of the heat pump proved lower than that of other methods of electric heating, a higher initial investment would be permissible. Comparative operating costs were determined both for assumed houses in selected localities and for actual houses now heated electrically. The increased investment permissible with the heat pump was then computed on the basis of a twenty-year life for the equipment.

In making comparisons two alternative methods of conventional electrical heating were considered, one, by means of a central furnace, which is more comparable to the heat pump, the other, by means of individual room heaters which are more commonly used. Computations for the heat pump were based on the use of well water or other ground heat, and on the use of outside air as a source of heat. In certain cases comparative costs for coal and oil were included. Consideration has also been given to summer air conditioning, an important item in some parts of the country in determining maximum permissible first cost.

Two alternative methods were used as a means of checking the results: first, a purely theoretical analysis based upon the pressure-enthalpy diagram in which all known loss correction factors were applied; second, the use of actual test data on refrigeration equipment submitted by two of the leading manufacturers.

Of several available refrigerants considered for this study, the only one used in the computations was Freon-12 which is the lowest in cost, has operating characteristics equal or nearly equal to the others, and is the only one for which adequate tables are readily available.

Two different sources of heat were considered for the heat pump. In the northern states the use of well water or buried pipes appears to be most satisfactory, while in the South, air seems to provide a satisfactory source of heat. Thus far no definite information is available for the design of suitable equipment for heat extraction or for the selection of the most suitable type for a given climate, but a number of studies on this subject are now under way, including the one at the University of Washington.

Conclusions. The computations for the part of the study including economics and operating characteristics already published (*Experiment Station Technical Note No. 6*), may be classified into two parts.

The results of the first part, those of the operating characteristics, are presented in five sets of curves by the aid of which the capacity of the equipment needed and the yearly cost of the energy consumed can be determined for a given heat-pump installation. The results of the second part of the study, those of the comparative costs, show that, at the present prices of coal and oil, only heat-pump installations with a coefficient of performance of 2.00 or better and with electric energy at one cent or less per kwhr can produce heat at an equal or lower cost than burning the fuel directly in the furnace.

Graph No. 8, reproduced here from *Technical Note No. 6* (Fig. 1), gives an interesting comparison of the cost of a million Btu of heat by means of the various most popular heating methods, at various energy or fuel costs. Another interesting comparison might be stated as follows. With electric energy at 7-1/2 mills per kwhr for heat, one million Btu will cost $2.20, while the same heat produced by a heat pump running at the rather low coefficient of performance of 2.00 will cost $1.10. To produce the same amount of heat for $1.10, oil must sell at 8 cents per gallon when burned at a furnace efficiency of 60 per cent while coal must sell at $12.00 per ton when burned at a furnace efficiency of 50 per cent.

PROGRESS ON LATER PROJECTS

At the time of completion of the first report on the heat pump study, the intense interest of the public in this mechanism and the fact that many installations were either in process or contemplated revealed a host of problems for further consideration.

An extensive study of the factors involved in designing and installing a grid of buried pipes for absorb-

*Abstracted from *Engineering Experiment Station Technical Note No. 6.*

ing heat from the soil, which appeared to be the project needing most immediate attention, was chosen as the next primary objective. However, to cover completely the necessary field and also to keep in touch with progress in the field, the new work might be classified into these four projects: (1) study of units operating in the practical field; (2) collecting as many data as possible on the temperatures at various depths throughout the year in the earth, lakes, sound, or any other possible heat sources; (3) obtaining experimental data on the amount of heat collected by pipes buried in the soil, for various depths, varying moisture content, etc; (4) making extensive studies of the heat conductivity of soils at various moisture contents and various average ground temperatures in the useful range above and below freezing.

First Project. During the past year a rather complete set of data was obtained on a heat-pump installation in a six-room house near the campus. From the year's record, not as yet completed, perhaps the following comments are of greatest interest.

Maximum monthly heating cost was in January and calculated at 7 mills per kwhr was $8.30. The average heat delivered to the house while operating was about 37,500 Btu per hour. The average coefficient of performance of the heat pump only, was 2.67. The average over-all coefficient of performance (including water pump, etc.) was 2.00. Work of this type will be continued.

Second Project. During the year several installations of temperature-measuring devices were placed at various places, with measurements from near the surface to as much as 50 feet below the surface. A considerable amount of data has been obtained but work must be continued through a year or more. Lake and sound temperatures were also found available and will be reported later.

Third Project. The purpose of this project is to obtain economic data regarding the use of ground grids and to supply engineers with definite factors for use in design work.

A sizable grid of copper tubing was buried two feet below the surface, and refrigerating and measuring equipment provided to obtain data on the heat-collecting capacity for ground grids. Reports from other sources range from about 7 to 16 Btu per hr per sq ft surface per deg F difference in temperature. Tests by workers on the present project show values about 8 Btu per hr per sq ft per deg F, with moisture content of the ground about 13 per cent, though more careful runs later may alter this figure somewhat. At low moisture contents the value drops to more like 4 or 5 Btu per hr per sq ft per deg F.

The next step will be to use pipes buried to 4- and 6-ft depths.

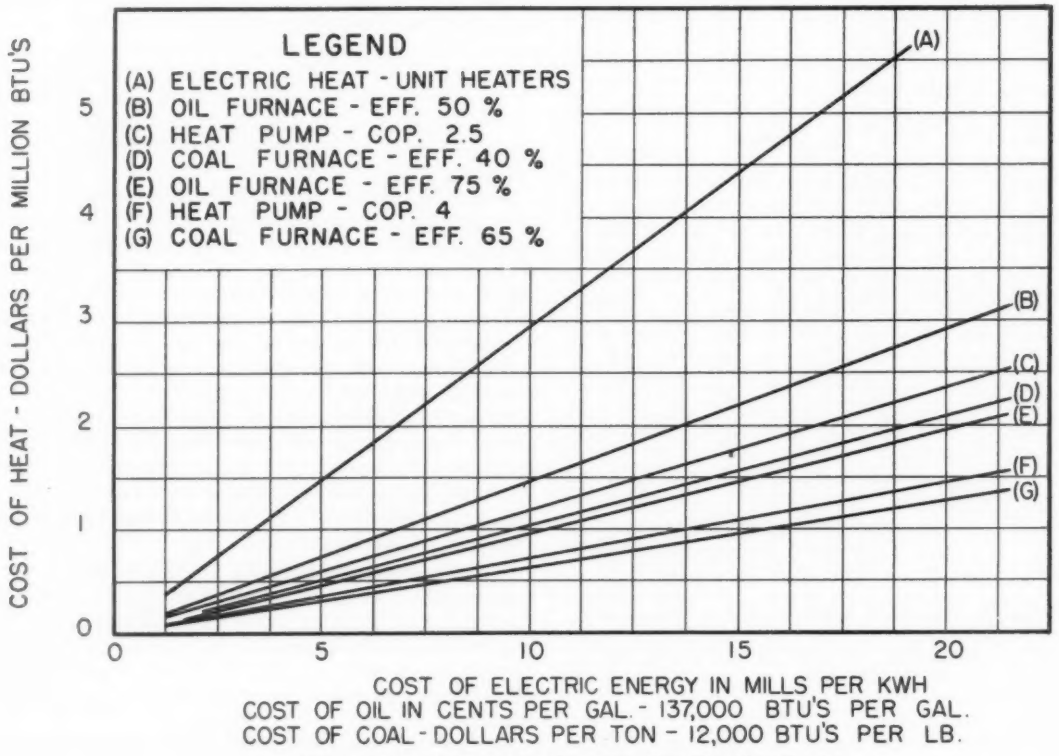

LEGEND
(A) ELECTRIC HEAT - UNIT HEATERS
(B) OIL FURNACE - EFF. 50 %
(C) HEAT PUMP - COP. 2.5
(D) COAL FURNACE - EFF. 40 %
(E) OIL FURNACE - EFF. 75 %
(F) HEAT PUMP - COP. 4
(G) COAL FURNACE - EFF. 65 %
COST OF HEAT - DOLLARS PER MILLION BTU'S
0
1
2
3
4
5
0
5
10
15
20
COST OF ELECTRIC ENERGY IN MILLS PER KWH
COST OF OIL IN CENTS PER GAL. - 137,000 BTU'S PER GAL.
COST OF COAL - DOLLARS PER TON - 12,000 BTU'S PER LB.

Fig. 1. Graph Showing Comparative Heating Costs

Fourth Project. This project is only well started, but its data, when complete, should greatly aid in applying other known factors, such as those obtained in Project Three, to any soils which could be subjected to conductivity tests.

In addition to what is apparently its advantage of lower long term cost, other factors also enter in to favor the heat-pump. Summer cooling, where desired, can be obtained from the same equipment with but little added expense; there is no soot or fumes, and but little dust; the fire hazard is extremely low; space normally required for chimney and for fuel storage may be devoted to other purposes. Where hydroelectric power is available, the use of the heat pump shifts the burden of heating from our expendable natural resources to one which is unexpendable, a factor of increasing importance as our natural resources are depleted.

RADIO WAVE PROPAGATION SURVEY

V. L. Palmer

Instructor in Electrical Engineering

The advent of frequency-modulation broadcasting in the 88- to 108-megacycle band and the prospects of television transmission in the Seattle area has raised a number of questions in regard to radiated power required and optimum antenna location for a given area of coverage. While a certain amount of data was available from eastern sources indicating the answers to such questions for propagation over relatively smooth earth, little was known about the effects of hills. Such information may best be obtained by direct measurement, and the information so secured, in addition to academic interest, would be of benefit to the broadcasters in this area. Accordingly, a project was started under the sponsorship of the University of Washington Engineering Experiment Station.

At the present time two general methods of attack are available for calculating the field intensity at a given point under specified conditions of transmitting and receiving antenna heights, radiated power, and terrain.[1,2]

By the first, one may calculate the field of the direct and reflected waves and then make other corrections for the effect of terrain based on diffraction theory. This method of calculation yields values in good agreement with the measured values at relatively short distances but is rather laborious to apply.

The second method, Norton's, assumes a smooth earth and is essentially a calculation of the surface wave as a function of distance and ground constants and the multiplication of the values so obtained by antenna height and distance factors. The solution is aided by using prepared charts showing the variations of the various factors in terms of dimensionless constants that must be determined for each problem. The Federal Communications Commission has published ground-wave charts that indicate, for an assumed set of average ground constants the field intensity as a function of distance for given antenna height at the transmitter and given values of power radiated. Though an excellent guide when used over smooth terrain, the method fails to take into account the effects of hills and other obstructions and is therefore in error in proportion to the magnitude of such effects.

Measurements in the high-frequency range over rough terrain with a relatively low receiving antenna

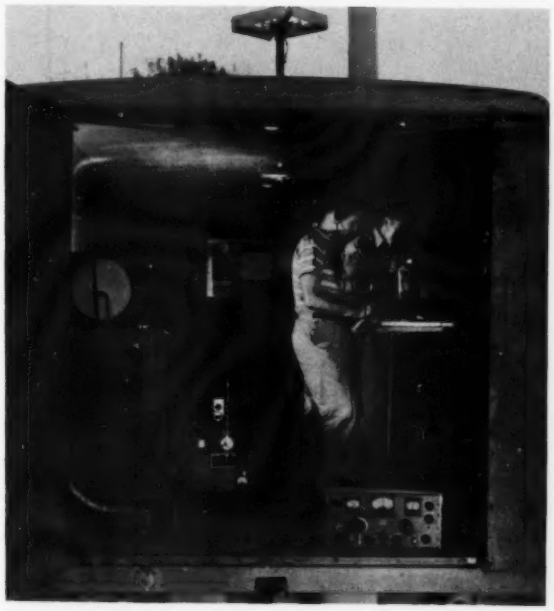


Fig. 1. Truck with Equipment for Taking Mobile Measurements

1. C. R. Burrows and M. C. Gray, "The Effect of Earth's Curvature on Ground-Wave Propagation," *Proc. IRE*, Vol. 29, No. 1 (Jan., 1941),pp. 16-24.

2. K. A. Norton, "The Calculation of Ground-Wave Field Intensities over a Finitely Conducting Spherical Earth," *Proc. IRE*, Vol. 29, No. 12 (Dec., 1941), pp. 623-639.

are subject to extremely large variations. Because of diffraction and reflection from objects in the vicinity of the transmission path the readings of field strength may vary in the ratio of ten to one with a movement of the receiving antenna of only a few feet. For this reason spot or single point measurements are of little value in attempting to determine the mean field intensity at a given location. A practical method of overcoming this difficulty is to make mobile measurements, obtaining an inked recording of the field intensity as a function of distance. Accordingly, a field strength meter, ink recorder, sensitive altimeter, engine generator, and a non-directional antenna were mounted in an army truck, an interior view of which is shown in Fig. 1. A rather exacting calibration and checking procedure has been followed in order to realize as high an order of accuracy as possible. While the absolute accuracy is of the order of 10 per cent the reset or comparative accuracy is about 2 per cent. The data so obtained may then be subject to any one of a number of methods of analysis and reduction.

Measurements are usually made as nearly as possible along radial paths from the station. The data obtained from the chart recordings contain large variations that may be attributed to multipath reflection, diffraction, and scattering from objects in the immediate vicinity and along the transmission path. In order to present the data in more usable form, the average of the signal strength over specified distances is obtained from the recordings and plotted as a function of distance from the station.

The first phase of the project, measurement of field intensity in the vicinity of 100 megacycles, has been completed. The results of the survey indicate that the F.C.C. Ground-Wave Charts yield values of mean signal strength to be expected larger than the actual measured values. It has been found possible to make a calculation for line of sight conditions which will yield values within a few decibels of the actual field. If line of sight conditions do not exist the calculation of the field intensity is very difficult. The survey, to date, indicates that the actual signal loss may vary as much as 20 decibels over the theoretical diffraction loss. Since the loss in transmission to a point behind a hill is influenced by irregularities of the hill, trees, buildings, and other obstructions, a reasonable evaluation of the loss based upon the smoothed profile of the hill seems rather improbable.

Work on the survey at the present time is concentrated in the vicinity of 50 megacycles with preparations being made to conduct surveys near 200 and 500 megacycles. A certain amount of effort is also being directed toward the measurement of distortion due to multipath transmission at these frequencies.

LOW-DENSITY SUPERSONIC WIND TUNNELS

G. E. Ledbetter
Research Associate in Aeronautical Engineering

The recent attainment of a test-section Mach number of 3.0 (1360 mph) in a small wind tunnel represents a significant point in the development of the supersonics facilities of the University of Washington Aeronautical Laboratory.

Design studies were begun by the Laboratory in the fall of 1946. The work was accelerated late in 1947 by assistance from the Engineering Experiment Station, and at that time construction work was begun on two small supersonic wind tunnels.

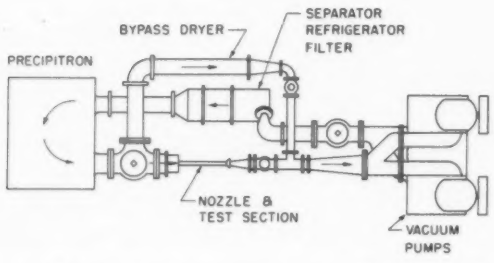


Fig. 1. Schematic Arrangement of UWAL 1- by 2-in. Supersonic Wind Tunnel

Both tunnels are to be operated nominally at atmospheric stagnation pressure. With isentropic flow through the nozzle, some idea of the test section conditions can be obtained from the basic flow equations:

$$\frac{T_o}{T} = 1 + \frac{\gamma-1}{2} M^2$$

$$\frac{P_o}{P} = \left(\frac{T_o}{T}\right)^{\frac{\gamma}{\gamma-1}}$$

$$\frac{\rho_o}{\rho} = \left(\frac{T_o}{T}\right)^{\frac{1}{\gamma-1}}$$

For air, the ratio of specific heats, $C_p/C_v = \gamma$, is 1.40. Assuming isentropic flow at a Mach number of 3.0 the test-section air density, ρ, will be 0.076, the free-stream temperature, ρ_o, will approach -275F, and the pressure will drop to 0.4 psia.

The first tunnel to reach the preliminary testing stage has a 1- by 2-in. test section with a two-dimensional nozzle. Through use of a 15-hp Stokes model 612E vacuum pump and a closed return (Fig. 1) it will be possible to vary the stagnation pressure

from 10 psia to 25 psia. This will allow the control of test-section density.

The vacuum pump is an oil-seal rotary type with a design theoretical displacement of 500 cfm. For use with the 1- by 2-in. tunnel, larger driving pulleys were required to give an actual displacement of 530 cfm at the pump inlet pressure of 3.5 psia. A considerable amount of oil "smoke" is passed with the pump exhaust throughout the entire useful pressure range, necessitating a thorough cleaning of the air before its re-use. To accomplish this, the exhaust air is successively passed through a refrigerated cyclone separator, a refrigerator, an absorbing filter, several precipitron cells, and, finally, a heating section.

Moisture in the circuit air will be removed initially by pumping the air several times through a by-pass silica gel dryer. During a run, partial control may be effected by the refrigerator used for oil smoke control.

The small tunnel is to be used for stream-tube studies. A duct of this size works effectively with boundary layer and supersonic diffusion. In addition to the variable density feature, the driving pump is suitable for use with interchangeable nozzles for Mach numbers through 6 or more with the 1- by 2-in. test section.

The larger tunnel, now under construction, will have a 3- by 3-in. test section for a two-dimensional nozzle and a 3-in. diameter jet for a three-dimensional expansion. The tunnel will be driven intermittently by two large vacuum tanks. It will require 25 minutes to evacuate their combined volume of 1575 cu ft to a pressure of approximately 0.05 psia, sufficient for a 30-second test run at M = 3. Pump-down time between runs will be about 20 minutes.

Evacuation for the intermittent tunnel will be performed by a 25-hp Kinney DVD 141418 oil-seal rotary vacuum pump. This pump, which has a theoretical displacement of 475 cfm, will be run during the tunnel "blow-down" to increase the test time by 5 per cent at M = 3.

While such a large pump is not necessary for this arrangement, the Laboratory was fortunate in obtaining the Kinney pump, together with an 875-cu ft altitude chamber, on loan from the U.S. Air Forces.

The ordinates for the nozzles were laid out by the conventional graphical method of characteristics. Boundary layer corrections were estimated using incompressible flow data, and checked by existing (sparse) experimental data. Provision for further boundary layer correction was made in the 1- by 2-in. tunnel by building in a jack-screw adjustment on the downstream end of the upper nozzle block.

Both two-dimensional tunnels are equipped with 1/4-in. plate-glass side walls extending from upstream of the nozzle throat to downstream of the supersonic diffuser.

The nozzle blocks for the small tunnel are made

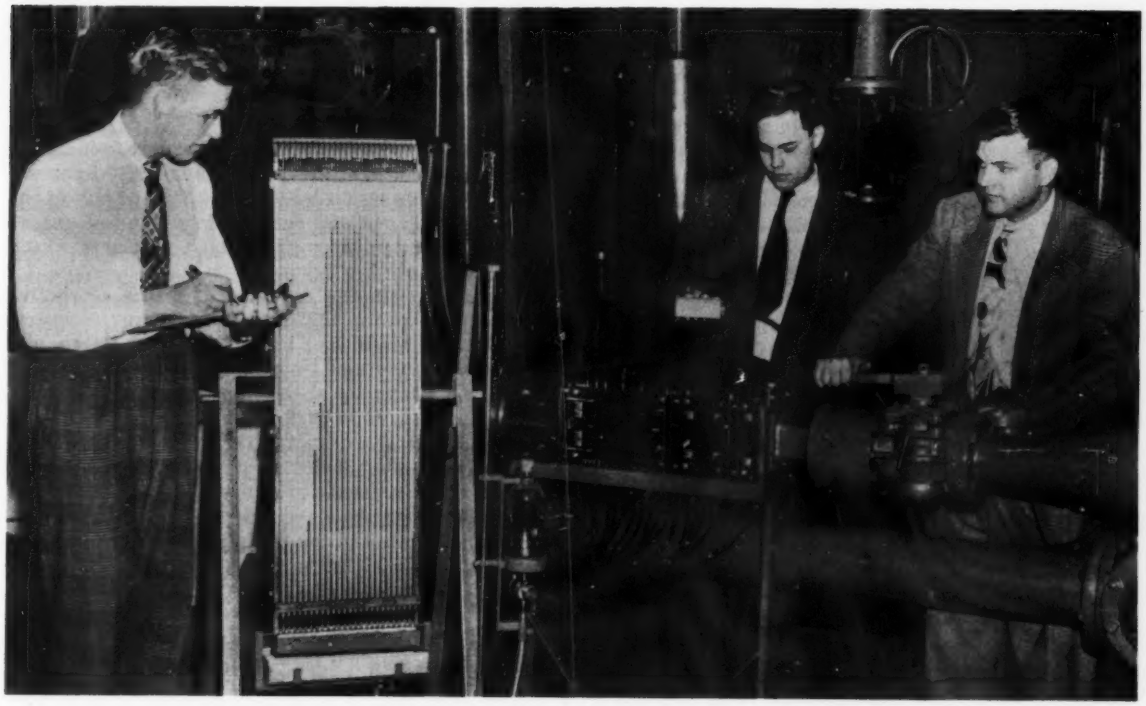


Fig. 2. Preliminary Calibration Tests on 1- by 2-in. Nozzle

of lignum vitae, a hardwood with approximately the same thermal expansion coefficient as the glass walls. The wood-glass seal is accomplished by a rubber gasket in an undersized groove in the wood. Sealing pressure is applied by pad-type clamps assisted by the pressure drop across the glass.

The 3- by 3-in. tunnel is similar in design except that mild steel nozzle blocks will be used with a sliding expansion seal at the downstream end of the glass.

The nozzle blocks for both tunnels were ground parallel to the airflow, thus reducing the possibility of finite discontinuities across the airstream.

Fixed supersonic diffusers are used in both ducts. The diffuser sections are removable and are equipped with interchangeable liners. In the 3- by 3-in. tunnel, the model will be mounted on a sting extending forward from a biconvex strut in the diffuser section.

The laboratory optical system is a conventional double-pass schlieren arrangement (Fig. 2). The intense mercury-vapor light source (G.E. BH-6 lamp) is masked to form a rectangular slit source at the focal point of an 8-ft focal length, 6-in. diameter parabolic mirror. The parallel light travels through the walls of the test section, is reflected from a plane mirror back through the tunnel to the parabolic mirror, and is then focused at a point several inches from the light source. Both the slit source and the knife edge can be rotated through 180° to provide sensitivity at the desired angle.

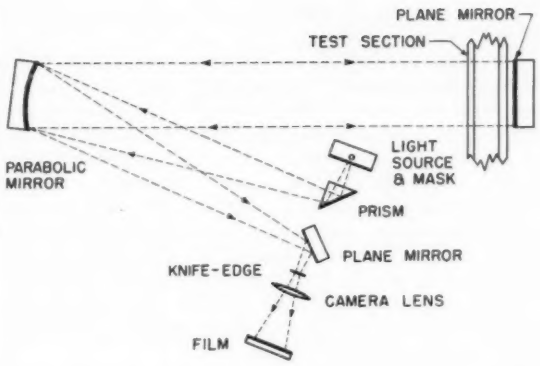
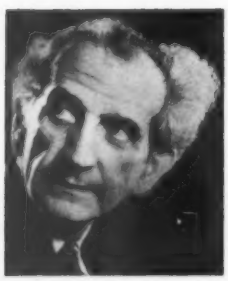


Fig. 3. Schlieren Optical System

Nozzle calibration tests are currently being run on the small tunnel by means of measuring local static pressure and the stagnation pressure (Fig. 3). A 25-tube mercury manometer is used to read static pressures at points through the nozzle and test section. Increased accuracy will be obtained in future tests through use of a small pitot tube in the airstream.

Although much development work must be done before the tunnels are ready for laboratory use, theoretical studies are now under way in the Laboratory in the fields of supersonic diffusion and of boundary layer, while preliminary studies are being made in the field of superaerodynamics.

THE LANCZOS LECTURES ON THE FOURIER SERIES



Cornelius Lanczos
Photo by Kassawitz

Jointly sponsored by the Engineering Experiment Station and the Walker-Ames Lectureship Foundation, Dr. Cornelius Lanczos, noted physicist and mathematician, was brought to the campus for the Fall Quarter of 1947-48 to give ten lectures on the Fourier Series and its applications. The lectures, though on the technical level of faculty members and a few advanced graduate students in engineering, mathematics, and physics, aroused so much interest in the wider circle of the less well-informed as to necessitate moving the crowd to larger quarters.

The majority of his listeners, who failed to follow Dr. Lanczos through all the intricacies of his mathematical formulas, were held to the end by the new significance of ordinary procedures as revealed in the light of his philosophical approach, by his delightful sense of humor, and by the force of his dynamic personality.

In the Epilogue following his ten lectures Dr. Lanczos explained the basis of their plan, which was to show that however diversely the specific interests of his audience might be directed toward any of the physical sciences and various branches of engineering, "Mathematics provided a platform which united them all."

According to his autobiographical sketch, Cornelius Lanczos was born in 1893 at Szckesfchervar, Hungary, and received his higher education at the University and Polytechnicum of Budapest. From 1921 to 1931 he taught in Germany at the Universities of Freiburg and Frankfurt. In 1928-29 his studies in relativity brought him into contact with Einstein. In 1931 he came to the United States as professor of mathematics and mathematical physics at Purdue University. In 1945 he resigned his professorship to join the Physical Research Unit of the Boeing Aircraft Company in Seattle as Research Engineer. During the Fall Quarter, 1948-49, Dr. Lanczos is giving a course on relativity in the Physics Department of the University of Washington. He expects to leave Seattle at the beginning of 1949 to take up his new duties as Research Mathematician at the Institute for Numerical Analysis under the U.S. Bureau of Standards.

AERODYNAMIC STABILITY OF THE NEW TACOMA NARROWS BRIDGE

F. B. Farquharson

Professor of Civil Engineering

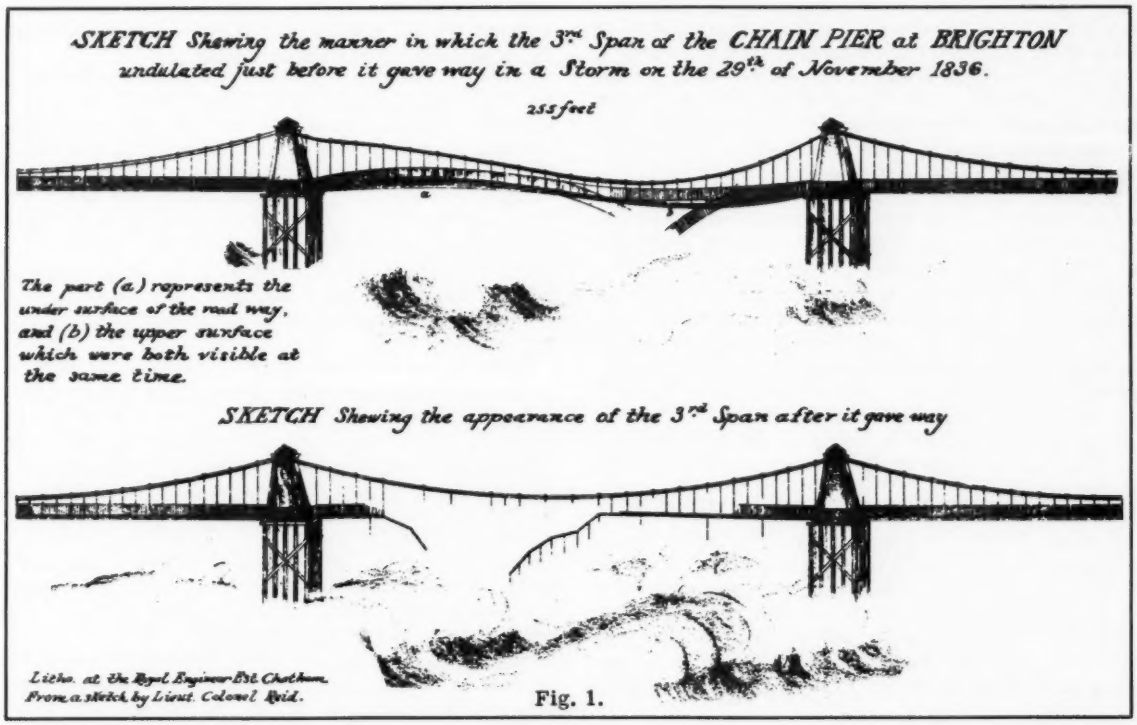

SKETCH Shewing the manner in which the 3rd Span of the CHAIN PIER at BRIGHTON undulated just before it gave way in a Storm on the 29th of November 1836.
255 feet
a
The part (a) represents the under surface of the rail way, and (b) the upper surface which were both visible at the same time.
SKETCH Shewing the appearance of the 3rd Span after it gave way
Litho. at the Royal Engineer Est. Chatham. From a Sketch by Lieut. Colonel Reid.

Fig. 1.

Records of suspension bridges show that the nineteenth century, so fruitful in many mechanical developments, contributed little to the art of designing such bridges to withstand the action of wind. The illustration in Fig. 1, taken from a paper written in 1839[1], is a copy of a sketch by Lt. Col. Reid of the Corps of Royal Engineers, later Governor of Bermuda. Colonel Reid observed the failure of the Brighton Chain Pier on November 29, 1936, and sketched it on the spot. Thus, almost exactly 104 years before the failure of the Tacoma Narrows Bridge, a much smaller suspension bridge suffered a similar fate.

The Brighton Chain Pier failure, cited as an example merely because it provides a good sketch by a reliable witness, was typical of four other wind failures which occurred in the British Isles during the early part of the nineteenth century. In 1834 a similar failure occurred in Germany, and in 1852 a French bridge failed, followed in 1854 by a failure in this country at Wheeling, West Virginia.

The span which failed at Brighton was only 255 feet long; the French bridge at Roche-Bernard, 641 feet; and the bridge at Wheeling, 1,010 feet. Ten years after the failure of the Wheeling bridge, a bridge of similar size over the Niagara River suffered severe damage due to wind.

The years between 1882 and 1940 saw great and successful development of this most graceful type of structure, but a newcomer in the field of such design would search in vain in the established literature for any lore covering the many sad experiences with wind during the early period of its development.

All of the spans which failed during the first half of the nineteenth century were small structures of no great weight and possessing little stiffness beyond that deriving from the geometry of the cable. It was therefore most natural to attack the problem of wind undulation first through stiffening up the handrails, which, in the natural process of evolution, became

1. John Scott Russell, M. A., F.R.S., "On the Vibration of Suspension Bridges and Other Structures," *Trans. Royal Scottish Society of Arts*(1841), Vol. 1.

stiffening trusses and ultimately, as design succeeded design, developed into structures of considerable proportions.

In the course of time these structures were called upon to support rail traffic, and the problem of grade change as the load progressed across the span forced still further stiffening through deeper trusses. In some instances, notably at Brooklyn, multiple diagonal stays were used to augment the stiffness; but there is considerable evidence that Roebling[2] used them primarily as insurance against wind.

The more recent trend in suspension bridges has been toward ever-increasing spans, with the result that diagonal cables have disappeared entirely and, except in the case of some double-deck structures, rail traffic has been eliminated.

In order to make these record-shattering free spans possible, the theory was re-examined and the doctrine promulgated that no more stiffness was required, in addition to that derived from the cable, than was necessary to restrain the change in grade to the maximum allowable with modern highway traffic. This practice, which was universally accepted, placed the art right back in the early nineteenth century and led to structures which, although sound from the point of view of the required static loads, were in danger of being as aerodynamically unsound as the early bridges which failed under the action of wind.

Thus, no voices were raised when the Tacoma Narrows Bridge, the world's third longest span, exhibited a pair of stiffening girders which, although 8 feet deep, were of a completely negligible stiffness in comparison with the cables and, as time soon showed, of a highly faulty aerodynamic shape. One hundred and thirty-two years had passed and suspension bridges were still being designed with no thought regarding the dynamic effect of wind.

In October, 1941, almost a year after the failure of the Tacoma Narrows Bridge, a project was set up in the Structural Research Laboratory at the University of Washington for the purpose of developing a shape for the suspended structure which would be aerodynamically satisfactory. This project was jointly financed by the Washington Toll Bridge Authority and the Public Roads Administration and reached what is confidently believed to be a successful conclusion in December, 1945.

In the course of these studies, a special wind tunnel and two full models were constructed. The models were built to a scale of 1 to 50, and numerous variations in the form of the roadway section were investigated. In addition, a large number of section models were built to the same scale, but only five feet long, and tested in the same wind stream. This section-model technique permitted the rapid evaluation of the merits of various proposed sections without the costly construction of the complete suspended structure, which was 100 feet long on the full models.

Space is not available in this brief article to permit an adequate description of the problems involved in this lengthy study. A more complete description of this investigation will be found in the references listed on page 23, and a complete report, in five parts, is now in the course of preparation, with Parts I and II now ready for the press.

In Fig. 2, the full model of the final design for the new Tacoma Narrows Bridge is shown, together with the section model which was used in developing the final form. A satisfactory degree of aerodynamic stability was achieved by replacing the original 8-foot plate girders by 33-foot trusses and opening up grating-covered slots on each side of the four driving lanes. The widening of the bridge resulting from the addition of two driving lanes was justified by increased traffic in the area.

2. D. B. Steinman, *The Builders of the Bridge*, New York, Harcourt, Brace, and Co., 1945, pp. 310-11.

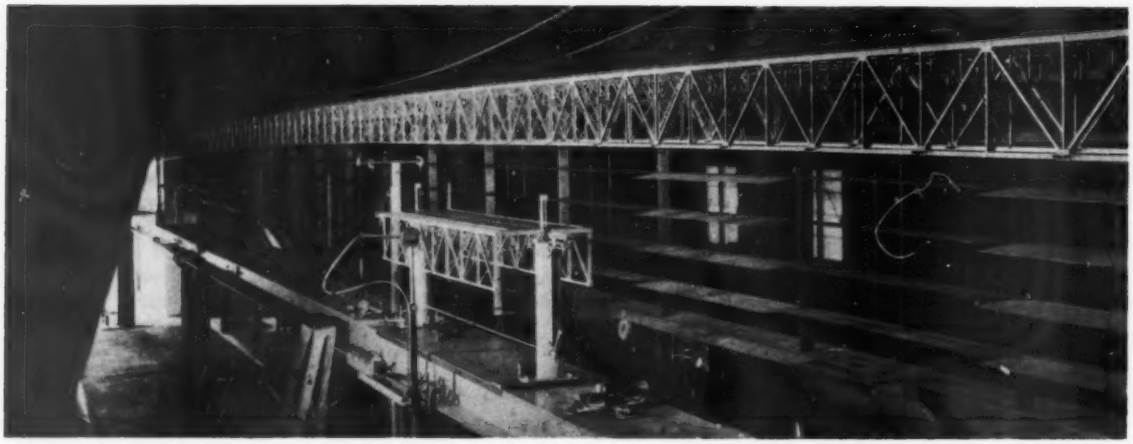


Fig. 2. Full Model of Final Design with Section Model Mounted Below in Position for Test.

THE ELECTRON MICROSCOPE SERVES A WIDE FIELD

O. H. Rowe

Electron Microscopist

The electron microscope acquired by the Engineering Experiment Station in January, 1948 is an instrument developed to probe the microscopic world as deeply as the mighty Mt. Palomar "eye" will probe the macroscopic. But while the giant telescope at Mt. Palomar owes its advantage over older telescopes to its greater size, the new microscope excels in its field by the use of a radically new principle.

The ordinary microscope uses light waves and a system of glass lenses to separate and enlarge minute objects to a size at which they can be seen and distinguished by the human eye. The best light microscopes are able to make visible an object 1/125,000th of an inch in diameter. Any object smaller than this would fail to be resolved when viewed through a light microscope-- that is, it would show no detail or character of its own. Such an instrument cannot be improved beyond this point by increasing its size or improving the quality of its glass lenses. If light is considered to be a wave motion the small but finite length of a wave of the light limits its sensitivity to small particles. Light cannot distinguish particles much smaller than, or closer together than its own wave length. If further penetration into the infinitesimal is desired, a substitute for light must be used.

Fig. 1. Mr. Rowe at the Microscope

In 1923 de Broglie proposed the revolutionary new theory that matter has a wave nature and that the electron, being a particle of matter, is composed of waves. The length of an electron wave was found to be dependent on the velocity of the electron which, in turn, is dependent on the voltage used to propel it. Under a potential of 50,000 volts, the average value used in most electron microscopes, the electrons reach a velocity about one-half the speed of light and have a wave length 1/100,000th that of light. Limitations in the mechanical construction of the magnetic lenses necessary for focusing and controlling the path of the electron beam and for maintaining a stable voltage at 50,000 volts prevent the attainment of the theoretical power of the electron microscope, but in actual practice the instrument is capable of distinguishing particles as small as 1/100,000,000th of an inch, with an ultimate magnification from 100 to 200 times greater than that possible with light.

The electron microscope at the Engineering Experiment Station has carried on investigations in such widely divergent fields as forestry, microbiology, zoology, metal surfaces, clay studies, and sewage analysis, and has already contributed to the world's knowledge in revealing several facts hitherto unknown. Its main use thus far has been in the study of wood structure where it has disclosed for the first time, insofar as is known, the relative arrangement of lignin and cellulose in the wood. In the field of microbiology it may have revealed a new method of reproduction among the lower orders of life. Further investigation is necessary in order to determine the significance of these new data.

The electron microscope has already proved to be an indispensable tool in technical research and industry, and will continue to play its part whenever greater resolving power is needed in any of the fields of science or industry which depend on knowledge of the submicroscopic, such as soil chemistry, ceramics, rubber research, smokes, large molecules, medicine,--in fact any field in which particles in the colloidal range are important.

However, the electron microscope is not omnipotent in research and industry. While the range of applications is very broad and the degree of value to any one field very high, definite limitations are imposed by the necessity of dealing with very small

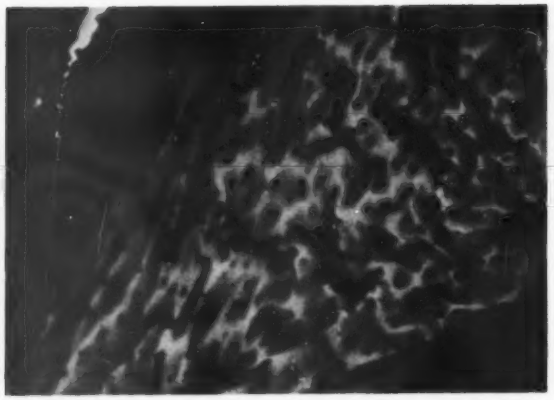


Fig. 2. Micrograph of a Section of Western Hemlock Wood Cut an Angle of 45° (x 44,000)

specimens and of observing them in a very high vacuum and under bombardment by a high intensity electron beam. Individual problems must be met by individual solutions, each type of specimen requiring its own method of preparation. However, as each solution is found and each method developed, man will be able to penetrate ever deeper into the hitherto invisible domain of the infinitesimal.

Ed. Note: Oliver H. Rowe, Electron Microscopist of the Engineering Experiment Station, who is responsible for operation of the microscope in the various fields he has described, received his B.S. with a major in chemistry from the State College of North Dakota. He has had two years' postgraduate work in physics at the University of Washington and a special course in electron microscopy at the University of Texas.

THE NORTHWEST CONFERENCE ON ROAD BUILDING

R. G. Hennes

Under the joint sponsorship of the Department of Civil Engineering and the University of Washington Student Chapter of the American Road Builders' Association, a three-day conference on road building was held in More Hall in February, 1948. The meeting and proceedings were widely reported in the technical press.

The attendance tabulation is indicative of the interest exhibited in this meeting. The 224 delegates fell into groups as follows:

City Engineers	29
Consulting Engineers	13
Contractors	10
County Commissioners	8
County Engineers	25
U.S. Navy Engineers	5
Industrial Representatives	51
Publications	3
State Department of Health	2
Federal Engineers	14
Washington State Highway	51
Unaffiliated	13
Total	224

In addition to the various groups of city, county, and state officials, were representatives from the British Columbia Research Council at Vancouver, B.C.; from the Civil Engineering departments of Washington State College, the University of California at Berkeley, and Seattle College.

The Conference was planned primarily to serve all engineers interested in the design and construction of roads and streets. The Department of Civil Engineering also used the opportunity to exhibit new laboratory facilities, and to mark the inauguration of a local student chapter of the American Road Builders' Association.

Judged by the program, this was the most important technical meeting on road building ever held in this region. Topics discussed in reports, round table discussions, and laboratory demonstrations included highway structures, drainage, pavements, asphalt, and subgrades.

Student participation in the arrangements and in the test demonstrations was instrumental in winning the Charles E. Upham Award, which was conferred upon the University of Washington Student Chapter, ARBA, in the 1948 Road Show in Chicago last July.

Representatives from private concerns, Washington Department of Highways, Public Roads Administration, West Coast Lumberman's Association, County and City Engineers, U.S. Engineers, and the Civil Engineering Department, University of Washington, were among the men participating from the speaker's table.

The Second Northwest Conference on Road Building will be held February 7, 8, and 9, 1949. Prominent engineers from California, Oregon, Washington, Michigan and Idaho have indicated their willingness to contribute to the program. The general coverage will be patterned after the 1948 Conference, with emphasis on asphalt, concrete and subgrade. In addition, the matter of participation by political subdivisions of the State in the Federal Aid Program will be a subject of general interest.

Proceedings of the 1948 Conference have been published by the Engineering Experiment Station, and are now available at $1.00.

STRENGTH OF LARGE CONCRETE PIPES *

W. R. Mason

Instructor in Civil Engineering

The increasing use of large reinforced concrete culvert pipe has necessitated laboratory tests by the two recognized ASTM methods: the three-edge and the sand-bearing. At the present time the ASTM and the Washington State Highway Department specifications give the ratio of the required load-carrying capacity by the three-edge method as two-thirds of the load required when tested by the sand-bearing method, regardless of pipe size. The Iowa State College Experiment Station developed this ratio from experiments performed on 30-in. and smaller diameter pipe; subsequently, without further investigation, this ratio was extended to include all sizes.

In August, 1947, at the request of the Washington State Highway Department, the author conducted tests by the two methods on the larger diameter culvert pipes (36-in., 48-in., 60-in., and 72-in. diameter) to determine the validity of the 1.0 to 1.5 ratio for these sizes. Forty large culvert pipes were tested in the Structural Research Laboratory, Civil Engineering Department, University of Washington, using the University's new 2,400,000-lb testing machine which was well suited, because of its size, for performing these tests. The circular pipes were of extra strength design, having tongue-and-groove ends. The specifications designated 4,750-psi concrete.

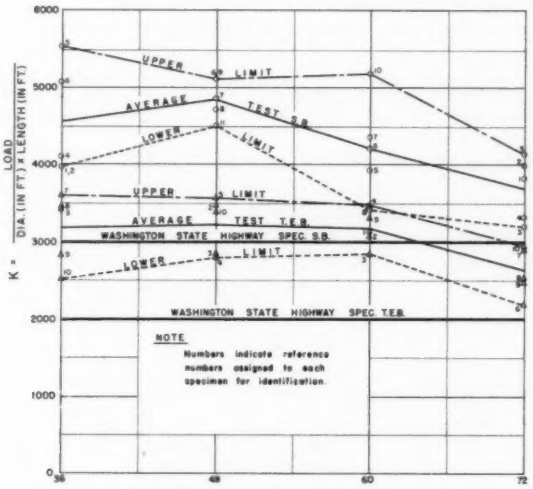

K = LOAD / DIA. (IN FT) x LENGTH (IN FT)
UPPER LIMIT
AVERAGE TEST S.B.
LOWER LIMIT
UPPER LIMIT
AVERAGE TEST T.E.B.
WASHINGTON STATE HIGHWAY SPEC. S.B.
LOWER LIMIT
WASHINGTON STATE HIGHWAY SPEC. T.E.B.
NOTE
Numbers indicate reference numbers assigned to each specimen for identification.

Fig. 1. Test Results for 0.01-in. Crack Load

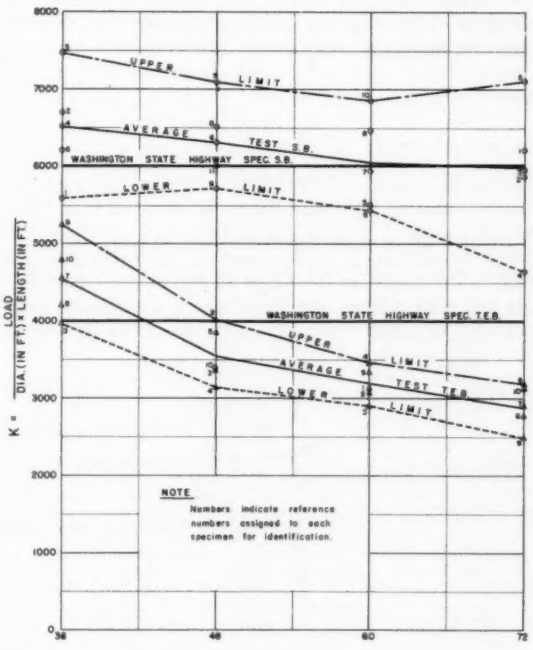
*Abstracted from W. R. Mason, "Strength of Large Concrete Pipe," *Proceedings, 1948 Northwest Conference on Road Building.*

TABLE 1. AVE. RATIOS OF STRENGTH BY SAND-BEARING METHOD TO THOSE BY 3-EDGE

Dia. of Pipe (Inches)	Ratio at 0.01 Crack	Ratio at Ultimate Strength
36	1:1.42	1:1.44
48	1:1.50	1:1.78
60	1:1.35	1:1.90
72	1:1.41	1:2.06

The results of these tests indicate that the ratio, 1.0 to 1.5, holds for the 0.01-in. crack loadings for these larger diameters, but that for the ultimate loading it fluctuates between 1.0 to 1.5 for the 36-in. diameter and 1.0 to 2.0 for the 72-in. diameter pipes, as shown in Table 1.

Measured deformations of the pipes indicate a degree of flexibility in reinforced concrete pipe that is greater than frequently recognized. As an example, a comparison is shown in Table 2 on the 72-in. pipe under sand-bearing loadings and the corresponding record reductions in vertical diameters (averages). Horizontal diameter increased correspondingly.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LOWER LIMIT
WASHINGTON STATE HIGHWAY SPEC. T.E.B.
UPPER LIMIT
AVERAGE TEST T.E.B.
LOWER LIMIT
NOTE
Numbers indicate reference numbers assigned to each specimen for identification.

Fig. 2. Test Results for Ultimate Load

This result indicates that the larger pipes located in actual fills deflect sufficiently to enable the passive pressure of the soil on the vertical or horizontal projection of the pipe to give added load-carrying capacity. Figs. 1 and 2 show the results of these tests.

It is concluded that further investigation should be made in order to review and revise all specifications covering this subject.

TABLE 2. FLEXIBILITY OF 72-IN. PIPE

Vertical Deflection (Inches)	Largest Crack (Inches)
1/2	0.01
1-	0.02
1-1/2	0.03
3-	0.06

HYDRAULIC PROPERTIES OF CULVERT PIPE *

H. K. Moritz

Associate Professor of Civil Engineering

Water acquires velocity at the expense of elevation. For a given headwater elevation, there is a limit to the quantity that a given culvert can handle. Each of the two elements, velocity and area, which make up the quantity, can increase only at the expense of the other, and thus compete with each other to prevent an ever increasing discharge. It can be shown that maximum discharge occurs when the velocity head is one-half the average depth; this velocity and depth are called "critical" and the slope required to produce this velocity is called "critical slope".

If the slope of the culvert is less than critical slope, the velocity head will be less than one-half the average depth. Flow at sub-critical velocities is controlled by friction, the quantity being expressed by the formula, $Q = AV$.

where

$$V = C\sqrt{RS}$$

which is known to all students of hydraulics as the Chezy formula. For any depth of flow, the cross-sectional area A and the hydraulic radius R can be found from tables. S is the slope of the water surface which is the same as the slope of the culvert for uniform and steady flow, and the Chezy coefficient C may be computed from a variety of formulas such as the Kutter, Manning, or Bazin formula. (See Fig. 1 for notation.)

If the slope of the culvert is equal to the critical slope, gravity forces overcome friction with critical velocity, and $C\sqrt{RS}$ is equal to the critical velocity V_c from which the critical slope is found to be

$$S_c = \frac{h_v}{R} \times \frac{2g}{C^2}$$

where h_v is the critical velocity head. This formula makes it possible to determine the slope that will be required to produce critical velocity in a given culvert flowing at a given depth. The critical velocity head of one-half the average depth added to the depth gives the required headwater elevation H. The quantity can be expressed in terms of diameter, thus:

$$\frac{Q}{D^{5/2}} = \frac{A}{D^2}\sqrt{2g}\sqrt{\frac{h_v}{D}}$$

If the depth for a given culvert is known, the critical slope and quantity can be solved directly from the above equations.

If however the depth is not known, but the headwater elevation H is known, the solution is not direct but can be accomplished laboriously by "trials", or can be solved easily by use of the accompanying graphs which were prepared by assuming various depths (actually d/D ratios), and computing for critical flow

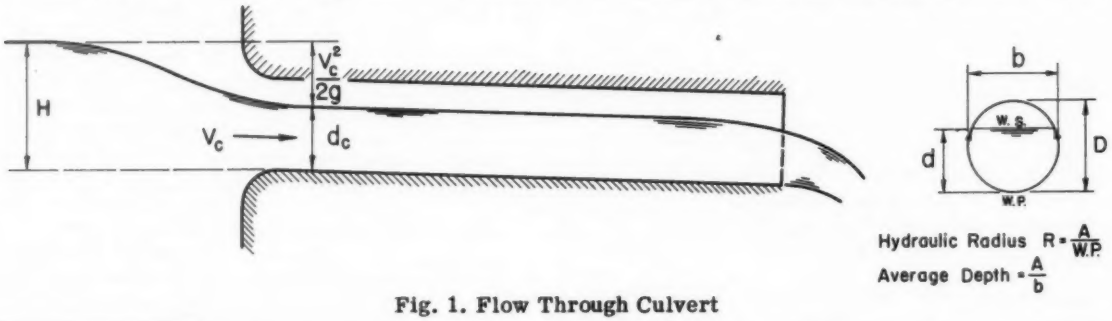


Fig. 1. Flow Through Culvert

*Abstracted from H. K. Moritz, "Hydraulic Properties of Culvert Pipe," *Proceedings of the 1948 Northwest Conference on Road Building.*

the values of H/D, S_c, and $Q/D^{5/2}$. For the rough culverts the Manning formula was used to determine values of C. The coefficient of roughness n was taken as 0.021. For the smooth culverts the Bazin formula was used with a coefficient of 0.1.

If the culvert slope is greater than critical, the quantity is controlled by the control section (where velocity head is one-half the average depth) which forms near the intake, and the increase in slope is *not* accompanied by an increase in quantity. Neither will roughness affect the quantity (as long as the slope is critical for that roughness) which depends upon what can get past the control section at the intake. If the culvert is placed on a slope steeper than critical slope, that quantity admitted by the control section will accelerate to velocities higher than critical velocities, but at depths less than critical depths, until stabilized by friction.

It should be noted that the critical slopes for culvert materials and sizes commonly used are quite low. For example, the critical slopes for all culverts, rough or smooth, one foot in diameter or larger, with headwater elevation level with the top of the culvert, is 2 per cent or less, smooth culverts being less than one-half per-cent.

The quantity given by the above equation and by the Q-graph (Fig. 2) will be admitted to the culvert only if the intake is rounded sufficiently to prevent contraction. A square-edged intake will produce a congestion at the entrance, because of the inability of the water to turn a sharp corner, with a consequent reduction in quantity. A radius of rounding equal to 14 per cent of the diameter is sufficient to give satisfactory results.

A square-edged or flush intake will give only about 85 per cent of the ideal discharge. A thin re-entrant one will give still less. The figures just mentioned, i.e.,14 per cent and 85 per cent, have been verified experimentally by the writer.

If the head H exceeds about $1.5\,D$ the culvert may not flow with a free water surface. If the head is sufficient so that the culvert will flow full, the problem is the same as for pipe flow; however, at the borderline condition, the culvert may flow alternately full and partially full, as though it were taking periodic gulps of air. The methods and data contained herein are to be applied only to cases where the headwater is not far above the top of the culvert, so that the culvert unquestionably flows partially full with a free water surface. A free overfall or get-away is also implied.

Tests have been run at the Hydraulics Laboratory of the University of Washington to determine the actual quantity discharged under various conditions. The values for the quantity discharged for rounded intakes on 6-in. pipe laid on a 5 per cent slope, and for 18-in. pipe laid on a slope of 1-1/2 to 1 are shown encircled on the Q-graph. Close agreement is seen to exist between the computed curves and the experimental points. A square-edged intake on the 6-in. pipe gave only 85 per cent of the discharge of the same pipe when equipped with a rounded intake. The standard concrete bell end permitted only 93 per cent of the flow that was obtained with the rounded intake. A head of 1-1/2 times the diameter was required to produce a flow through an 18-in. metal pipe with a re-entrant intake that was accomplished with a head of 1-1/6 times the diameter for the rounded concrete culvert. This difference is due solely to the intake, since the slope was sufficient to eliminate any influence that might be attributed to difference in roughness.

The following examples illustrate the use of the charts.

Example 1. Find the diameter and slope of rough culvert pipe required to carry 40 cfs, with headwater elevation level with the top of culvert $H = D$.

a. Enter Q-graph at $H/D = 1$ and at $Q = 40$ and intersection lies at $D = 3$ ft, which is the required diameter, provided the slope is critical or steeper.

b. Enter slope-graph (Fig. 3) at $H/D = 1$ and between 2-ft and 4-ft diameter curves for rough pipe; read slope about 1-1/2 per cent.

Note that a smooth culvert will handle the same quantity at slopes greater than about 0.35 per cent.

Example 2. Find Q for a 1-ft diameter smooth culvert, with $H = D$ and $S = 1$ per cent.

The slope-graph shows that the slope of the culvert is steeper than the critical slope; therefore the Q-graph applies, and Q is found to be about 2.5 cfs.

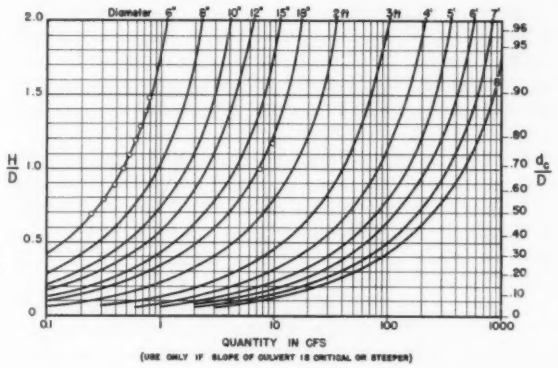


Fig. 2. Q-Graph

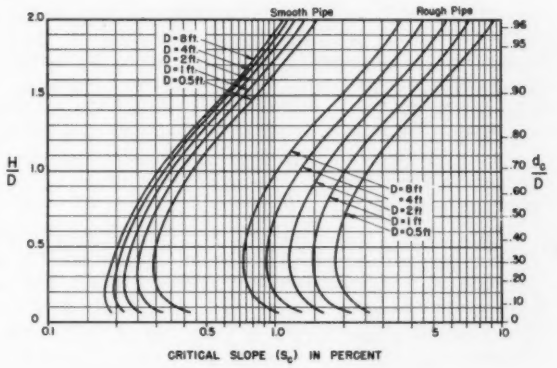
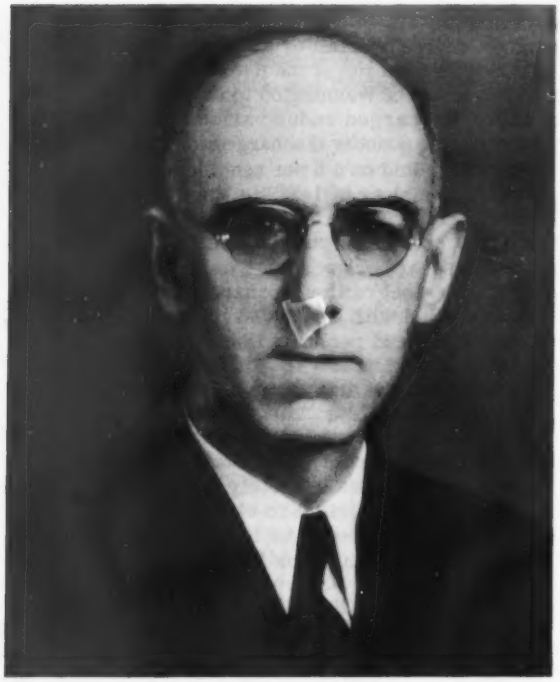


Fig. 3. Slope-Graph

DEAN LOEW ASSUMES ROLE OF ELDER STATESMAN



Edgar A. Loew

Dean Edgar A. Loew retired on September 1st from the active administrative duties which he has carried on in the College of Engineering continuously since 1935, to redevote his full time to teaching and research in his special field, power transmission.

From 1901, when he emerged with a diploma from the Teachers' College at Oshkosh, Wisconsin, prepared to teach high school physics and mathematics, the trend of his future interests was evident. After two years' teaching, he entered the University of Wisconsin where he earned his B.S. in E.E. in three years. In 1922 he received his professional E.E. degree from the same institution. Following his graduation, while engaged on the appraisal of the Minneapolis General Electric Company, he was urged by a former instructor, Professor Jackson, to go into teaching on the college level. As a result, in 1909 he came to the University of Washington as Instructor in Electrical Engineering, rising to the rank of full professor in 1923.

In June, 1917, impressed by the acute national need for nitrogen products cut off by the loss of the Chile market, he obtained leave of absence which lasted for the three years of his active connection with the American Nitrogen Products Company at La Grande, Washington, first as electrical engineer, later as plant superintendent.

In 1935 he assumed two administrative offices: Director of the Engineering Experiment Station, which he held until 1940, and Dean of the College of Engineering, recently relinquished because of retirement regulations. He has also frequently served as consultant for civic and regional projects requiring his special knowledge and experience. The more important of these include his work for the City of Seattle Light, and the Puget Sound Power and Light Company (1925), his study for the U.S. Engineer's Seattle Office resulting in the *Report on the Cost of Power Transmission from Columbia River Plants to Market Centers* (House Document No. 103 of the Seventy-Third Congress, 1933), and his work as consulting engineer for the Bonneville Administration (1941-) and for the Field Service, Division of Priorities, O.P.A. (1942-43).

Dean Loew's publications fall under two heads: those concerned with his technical research, and those prompted by his interest in engineering education. His two books, both published by McGraw-Hill, *Electrical Power Transmission* (1928), and *Direct and Alternating Currents* (three editions, 1933, 1938, 1946), have been in extensive use as textbooks. He was joint author with Professor F. K. Kirsten of Part II of *Transmission Line Design* (*Ex. Sta. Bull. No. 32*, 1925), and sole author of Part IV, "Choice of Line Voltage and Conductor Size" (*Ex. Sta. Bull. No. 50*, 1929). Numerous other contributions to this field have appeared in various technical publications. His "Production of Sodium Nitrite from Arced Nitrogen" (*Ex. Sta. Bull. No. 75*, 1933), prepared jointly with W. L. Beuschlein, grew out of his work at La Grande. Such addresses before the SPEE as "Trends in Engineering Curricula" (1933) and "What the Engineering College Expects of the Physics Department" (1940), and the article, "Public Service Rendered by the College of Engineering Staff" (*Northwest Industry*, 1942), reflect his concern with the professional training of engineers.

He is a member of the following organizations: AIEE (Fellow and Life Member); ASEE (Council 1946-48); ECPD (Delegatory Committee on Engineering Schools 1938-); Sigma Xi; Tau Beta Pi; Catalyst Club; Research Society (University of Washington); Newcomen Society of England; Faculty Club, and the Municipal League of Seattle.

His administration as Dean, which covered the war years and the most difficult period of post war adjustment, saw student enrollment in the College of Engineering increase from 1,180 to 2,060, the staff increase from 56 to 106 (exclusive of military), and degrees granted, from 132 to 412.

As Dean Emeritus he is teaching courses in power transmission and alternating-current theory this year and will continue to act as chairman of the Faculty Committee on Audio-Visual Activities.

DEAN WESSMAN STEPS TO HELM OF ENGINEERING COLLEGE

Dr. Harold E. Wessman, new Dean of the College of Engineering, comes directly from New York University where he has been chairman of the Civil Engineering Department for the past eleven years. As a recognized authority on the structural analysis and design of long span and movable bridges, he had previously been structural engineer with Waddell and Hardesty (now Hardesty and Hanover), who designed the Arthur Kill bridges, the Mississippi River Bridge at Cairo, the Hudson River bridges at Albany and Troy, the Maumee River Suspension Bridge, the Delaware River Bridge, and others.

Dean Wessman holds the degrees of B.S. (1924), M.S. (1925), C.E. (1929), and Ph.D. (1936), all from the University of Illinois where he was Instructor in Civil Engineering for two years following his graduation. During 1929-30 he was Associate Professor of Bridge Engineering in the Ministry of Railways University (Chiao-Tung University), Shanghai, China, and that year was also delegate to the World Engineering Congress in Tokyo. His connection with Waddell and Hardesty followed his return to the United States. In 1933 he became Associate Professor of Engineering at the University of Iowa where he remained for three and one-half years, leaving to accept the post of water commissioner and rate consultant for the city of Rockford, Illinois. During the past 15 years he has acted as consultant on various construction projects, chiefly on bridges and buildings and on aerial bombardment protection.

As an outstanding member of the ASCE, in 1940 he won the Norman Medal jointly with Shortridge Hardesty for the paper on "The Preliminary Design of Suspension Bridges," and during 1943-47 was director and vice-president of the Metropolitan Section, in addition to serving on important committees. In 1944 he was elected president of the American Institute of Consulting Engineers of which he had been a life member of the Council since 1942. His other professional affiliations include ASEE, International Association for Bridge and Structural Engineering, ECPD, Engineering Foundation (Research Procedure Committee 1938-46), American Institute of Steel Construction (Committee on Steel Structures Research), American Concrete Institute, Column Research Council (vice-chairman, 1948), Tau Beta Pi, Sigma Xi, Chi Epsilon, and Sigma Tau.

Dean Wessman is co-author of two books: *Aerial Bombardment Protection* (with W. A. Rose), published by John Wiley (1942) and *Vocational Guidance in Engineering Lines* (with J. A. L. Waddell and F. Skinner), published by the American Society of Engineers (1933), and he contributed the chapter, "Research in Rigid-Frame Bridges" to A. G. Hayden's book, *The Rigid-Frame Bridge* (John Wiley, 1940). Of his numerous important articles in technical journals some of the most recent are "Steel Arch Hangar Tested to Destruction," *Engineering News-Record*, October, 1947; "Tests of Metals Removed from Cables and Stiffening Trusses of Brooklyn Bridge," *Transactions of the ASCE*, Volume 112; "Reinforced Concrete Columns Under Combined Compression and Bending," *Journal of American Concrete Institute*, September, 1947; and "Mathematics in Civil Engineering," *Journal of Engineering Education*, December, 1946.

Harold E. Wessman
Photo by Harvey-Nelson

Dean Wessman was a member of the Committee of the ASEE which formulated the statement in 1940 "Aims and Scope of Engineering Education," and has also been a member of the Committee on Engineering Education of the ASCE for the past four years. In stating that his philosophy is well represented by the declarations of both of these committees, he points out that they have "emphasized that science and technology must dominate engineering education, but that, at the same time, a parallel stem of humanistic-social studies should be effectively presented to the engineering student in order to help him to discharge better his responsibilities in a modern society which is affected so much by the products of science and engineering."

BETTER PLYWOOD CHEAPER: PEELER LOG STUDY*

Roy C. Horne

Research Fellow, Engineering Experiment Station

To meet the demand for high quality logs necessary for the economical production of high quality plywood, the premium priced "peeler log" came into being. Studies by the writer indicate that with proper peeler log selection more high quality plywood can be produced and many of the present costly patching and handling operations can be eliminated. At present log buyers base their selection on the absence of visible defects, personal experience, and, perhaps, a little guessing. Since an "all-seeing eye" is not yet available to reveal hidden defects, an understanding of the manner in which Douglas fir forests grow, particularly during the first fifty years, will enable a buyer to select high quality peeler logs with considerable accuracy.

In 1930 McArdle and Meyer[1], investigating the quantity yield of Douglas fir forests, showed that physical factors including soil, drainage, rainfall, temperature, altitude, slope, and aspect, which, taken together are termed "site quality", all affect tree growth, and that the degree of stocking, or number of trees per acre, is also important. In 1939 Dr. B. L. Grondal, Professor of Forest Products at the University of Washington, suggested that the initial degree of stocking had a decided effect on the yield of quality veneer, as well, and that this could be determined by an inspection of the number of annual rings near the pith at the lower end of the butt log.

Trees in sparsely stocked areas or on the border of a dense stand, though increasing rapidly in individual volume resulting in greater diameter and less height, have many large branches low on the trunk, while those in a crowded stand, because of such factors as smaller soil space, fewer soil nutrients, and, especially, perhaps, the struggle for light, produce smaller diameter and greater height, and the limbs on the bole are small and die early. As a result, peeler logs from initially fully-stocked stands have fewer and smaller knots, and these are confined to the innermost portion of the logs.

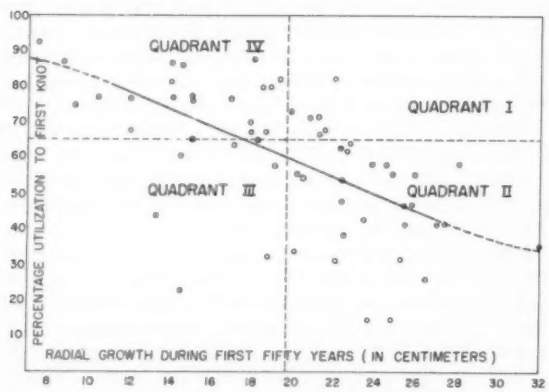


Fig. 1. Ratio of Utilization to Radial Growth

Sixty Douglas fir peeler logs were included in a sample and the following data recorded: (1) diameter on the small end after being barked (this ranged from 38 to 72 in. with an average diameter of 50.9 in.); (2) the radial growth from the pith outward for the first fifty years (this measurement varied from 7.5 to 32.0 cm with an average of 19.7 cm); (3) the diameter of the peeler block when the first knot appeared; and, (4) the diameter of the core when peeling was discontinued. (This core diameter is not statistically treated in this report). The basal area of the original log was computed and the area remaining after peeling to the first knot was also computed. The area of the annulus of wood outside of the first knot divided by the area of the original log times one hundred has been used as an expression of the percentage of utilization to the first knot. These data were tabulated. The percentage of utilization to the first knot has been plotted against growth during the first fifty years. This information appears in the graph shown in Fig. 1. The vertical line, separating quadrants I and II from quadrants III and IV, has its origin at the average growth point of the sixty logs, an average found to be 19.7 cm during the first fifty years. The horizontal line, originating at 65 per cent before the first knot, has been drawn arbitrarily for purposes of discussion.

Fig. 1 shows that of the sixty logs checked:

(a) Twenty-eight logs gave 65 per cent or more clear knot-free veneer. Of these twenty-eight logs, quadrant IV shows that twenty-two were below average (19.7 cm) in rate of growth during the first fifty years. The remaining six show an above-average rate of growth but in no case does this exceed 22.0 cm.

(b) Of the thirty-two logs which gave less than 65 per cent clear, twenty-six showed an above-average rate of growth. These appear in quadrant II. Only six of the thirty-two poorer logs showed a below average rate of growth.

(c) Percentage of clear veneer varied from 15 to 92 per cent. This certainly indicates the buyer's lack of understanding in peeler log selection.

In spite of the amount of dispersion shown in Fig. 1, much of it probably due to "site quality" variation, the correlation between rate of diameter growth during the first fifty years and the percentage of clear that can be cut is evident.

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*Abstracted from Roy C. Horne, "Better Plywood Cheaper: Peeler Log Study," *Timberman*, Mar., 1948.

1. R. E. McArdle and W. H. Meyer, "The Yield of Douglas Fir in the Pacific Northwest," *Tech. Bull. No. 201*, USDA, Washington, D.C., 1930.

NOTES AND COMMENTS

NEW ASSISTANT DIRECTOR

Warren W. Philbrick
Photo by Harvey-Nelson

Warren W. Philbrick, recently appointed Assistant Director of the Engineering Experiment Station, was graduated from the University of Washington in 1938 with a B.S. in M.E., and from the Harvard Graduate Business School in 1940 with a degree of M.B.A. Following some experience as a research engineer in Wisconsin, he spent five years with the Chicago Ordnance District of the U.S. Army where he organized and operated the Priorities and Expediting Branch. From 1944 to 1946 he served as assistant to the colonel who headed the Industrial Division.

After leaving the Army, in May, 1946, he established a laboratory to develop a low cost molding material from defibered wood. A year later, as Research Associate in the Experiment Station, he started work on developing processes for converting sawmill waste to board products. As Assistant Director of the Station and Assistant Professor of Mechanical Engineering he now divides his time between teaching and research and is also in charge of public relations for the Station.

RECENT REPRINTS

(Available at the Engineering Experiment Station)

No. 7. "Engineering Significance of Metals Testing," Blake D. Mills, Jr., *The Iron Age*, August 7, 1947

No. 8. "Aerodynamic Stability of Suspension Bridges," F. B. Farquharson, *Journal of the Western Society of Engineers*, September, 1947

No. 9. "Circuit-Breaker Current Measurements During Re-ignitions and Recovery," Laurel J. Lewis, *AIEE Transactions for 1947*

No. 10. "Products from Pulp and Pulpwood on the Pacific Coast," H. K. Benson, *Paper Trade Journal*, March 18, 1948

No. 11. "Better Plywood Cheaper; Peeler Log Study," Roy C. Horne, *Timberman* , March, 1948

No. 12. "A New Method in the Analysis of Complex Electric Waves," Walter E. Rogers, *Review of Scientific Instruments*, May, 1948

No. 13. "Extent of Peening Weld Deposits for Stress Relief," J. L. Morris, *Journal of the American Welding Society* , March, 1948

No. 14. "Separation of Lignin Sulphonic Acids from Sulphite Waste Liquor by Batch Dialysis," Nevin K. Hiester, Joseph L. McCarthy, H. K. Benson, *Paper Trade Journal*, April 15, 1948

No. 15. "Concept of the Graded Stream," J. Hoover Mackin, *Bulletin of the Geological Society of America*, May, 1948

No. 16. "Fodder Yeast Production from Sulphite Waste Liquor," Richard G. Tyler, William Maske, *Sewage Works Journal*, May, 1948

No. 17. "Electrolytic Ozone," G. L. Putnam, R. W. Moulton, W. W. Fillmore, and L. H. Clark, *Journal of the Electrochemical Society* , May, 1948

No. 18. "Strength of Large Concrete Pipe," William R. Mason, *Proceedings of the 1948 Northwest Conference on Road Building*

No. 19. "Hydraulic Properties of Culvert Pipe," Harold K. Moritz, *Proceedings of the 1946 Northwest Conference on Road Building*

No. 20. "Fatigue Under Combined Pulsating Stresses," H. Majors, Jr., B. D. Mills, Jr., C. W. MacGregor, *Journal of Applied Mechanics* , (in press)

STATION EXHIBIT

(Illustration, page 4)

The Experiment Station's exhibit at the Labor-Industry Exposition held in Seattle October 1 to 8 included Civil Engineering's machines for testing impact, torsion, and tension, Mineral Engineering's illustration of the method of using ultraviolet light to identify mineral specimens, and the use of a portable Geiger counter for radio-active materials, and Mechanical Engineering's demonstration of the use of polarized light to indicate stress patterns. The College of Forestry showed high-frequency gluing of wood as well as the method of cutting wood sections which could then be examined under microscopes set up for this purpose.

AERODYNAMIC STABILITY OF THE NEW TACOMA NARROWS BRIDGE

(continued from page 14)

Bibliography

Andrew, Charles E., "Design of a Suspension Superstructure to Replace the Former Tacoma Narrows Bridge, Part I," *Pacific Builder and Engineer*, October, 1945, pp. 48-53

_____ , "Redesign of Tacoma Narrows Bridge," *Engineering News-Record*, November 1945, pp. 64-69

_____ , "Unusual Design Problems — Second Tacoma Narrows Bridge," *ASCE Proceedings*, December, 1947

Farquharson, F. B., "Lessons in Bridge Design Taught by Aerodynamic Studies," *Civil Engineering*, August, 1946, pp. 344-345

_____ , "Aerodynamic Stability of Suspension Bridges," *Journal of the Western Society of Engineers*, September, 1948, pp. 141-152

RESEARCH PROJECTS OF 1948-49

Project 1. Experimental Field-Strength Survey
Supervisor: V. L. Palmer, Instructor in Electrical Engineering
Research Fellows: A. Lazarus, Oct. 1, 1947-
Hwa-Wei Chen, April 1, 1948-

Purpose: (1) to obtain a measured field-strength plot for the Seattle area for signals in the 50-, 100-, and 144-mc ranges, (2) to measure wave polarization at the receiving point to determine whether or not the antennae orientation at the transmitter is a deciding factor in providing a usable signal, (3) to observe and measure distortion of frequency-modulation wave due to multipath propagation, including measurements of path difference, number of arrivals, etc.

Project 3. Worm-Gear Investigation
Supervisor: L. B. Cooper, Assistant Professor of Mechanical Engineering
Research Fellow: Harold Tapay, Jan. 1, 1948-

Purpose: to investigate worm-gear units with a view to establishing more rational design methods by adapting or procuring input and output dynamometers, investigating test procedures, and making exhaustive tests on several units.

Project 4. Hardboard from Mill Waste
Warren W. Philbrick, Research Associate

Purpose: to develop a process for continuous production of hardboard or insulating board, from mill waste. Present processes involve too great capital investment in order to produce board at a competitive figure.

Project 5. Shearing Resistance of Soil and Aggregate
Supervisor: R. G. Hennes, Professor of Civil Engineering
Research Fellows: Harold Mason, Jan. 1 to July 1, 1948
J. B. Bennett, Oct. 1, 1948-

Purpose: to study factors affecting shearing resistance and stress-strain relationships, and to search for indicator tests for the prediction of shearing strength. The shearing strength of soil is of basic importance in all foundation, highway, and earthwork engineering. Shear tests are difficult to perform and interpret, and require facilities not available to many engineers and organizations.

Project 6. Stability and Durability of Bituminous Paving Mixtures
Supervisor: R. G. Hennes, Professor of Civil Engineering
Research Fellows: Ching C. Kuan, Jan. 1, 1948-
Hsing-Huan Chen, Oct. 1, 1948-

Purpose: to determine the modulus of rupture and the modulus of elasticity of bituminous paving mixtures under dynamic loading. This would permit design of flexible pavement thickness by rational methods now used for concrete slabs.

Project 7. Wave Action on Breakwaters
Supervisor: R. G. Hennes, Professor of Civil Engineering
Research Fellows: Jaime Goldemberg, Oct. 1, 1947-Aug. 1, 1948
James W. Harland, Oct. 1, 1948-

Purpose: to investigate wave action with reference to (1) safe slopes of rock fill for shore protective work, (2) wave pressure on walls and breakwaters, (3) development of translatory velocity in shoaling water, (4) effect of bottom slope and depth on wave form, (5) model studies of breakwater design.

Project 9. Experimental Check of Ground as a Source of Heat*
Supervisor: George S. Smith, Professor of Electrical Engineering
Research Fellows: L. L. Giller, Oct. 1, 1947 to Aug. 1, 1948
Louis C. Sutherland, June 1, 1948 to Oct. 1, 1948

Purpose: to continue experimental investigation of the heat pump in residential heating (*Exp. Sta. Tech. Note No. 6*) by measuring ground temperatures at various depths and obtaining data on the heat-collecting capacity for ground grids.

Project 10. High-Speed Cathode-Ray Oscillograph
Dr. Laurel J. Lewis, Assistant Professor of Electrical Engineering

Purpose: to design and construct a high-speed cathode-ray oscillograph for use in photographic recording of transient phenomena in high-voltage measurements and studies of insulation materials.

Project 11. Network Analyzer
Supervisor: Dr. Laurel J. Lewis, Assistant Professor of Electrical Engineering
Research Fellows: R. J. Ringlee, July 1, 1947 to Sept. 1, 1948
Hun-Hsuan Sun, April 1, 1948-

Purpose: to design and construct a network analyzer for the study of problems of power-system interconnections and for the training of graduate students in the theoretical approach to such problems. In large interconnected power systems, such as the Northwest Power Pool embracing Washington, Oregon, Idaho, and Montana, determination of the effects of short circuits and other faults in the system becomes extremely difficult. Such electric network analyzers as have been designed are so costly that only a few are available. The only one in the Northwest, owned by the Bonneville Power Administration in Portland, is unable to meet the demands for its use.

*In co-operation with the Bonneville Power Administration 1947-48.

Project 12. R-F Heating at High Frequencies

Supervisor: W. R. Hill, Associate Professor of Electrical Engineering

Research Fellows: Thomas Stuelpnagel, Oct. 1, 1947 to Aug. 1, 1948
Chi-Yuan Lee, Oct. 1, 1947 to Aug. 1, 1948
Miss Frances Cheng, Oct. 1, 1948-
Pao-Chuan Yu, Oct. 1, 1948-

Purpose: (1) to study the dielectric heating of solids with regard to temperature distribution, the prediction of this distribution, and the measurement of temperature in samples undergoing dielectric heating, (2) to develop equipment for measuring the electrical properties of dielectric samples for the purpose of obtaining useful information regarding typical materials, and (3) to develop equipment for measuring the thermal properties of these materials for use in predicting their behavior when heated.

Project 13. Distributor Beams on Laminated Wood Slabs

Supervisor: A. L. Miller, Professor of Civil Engineering

Research Fellow: R. W. Rowse, Oct. 1, 1948-

Purpose: to continue experimental verification of the theory and the physical behavior of miniature laminated wood slabs.

Project 14. Aerodynamic Stability of Suspension Bridges*

Supervisor: F. B. Farquharson, Professor of Civil Engineering

Principal Highway Bridge Engineer: G. S. Vincent

Research Assistant: R. E. McHugh

Research Fellows: R. M. Glick, Oct. 1, 1947 to Aug. 1, 1948
Kuo-Tsun Chang, July 1, 1948-
Fu-Chao Ho, Oct. 1, 1948-
Lars Skjelbreia, Oct. 1, 1948-

Purpose: to investigate the aerodynamic properties of suspension bridges with special reference to problems involved in the redesign of the Tacoma Narrows Bridge.

Project 15. Gluing to Raise Grade of Common Lumber

Supervisor: Bror L. Grondal, Professor of Forestry

Research Fellows: Harry Bartels, Oct. 1, 1947 to Aug. 1, 1948
Roy C. Horne, Oct. 1, 1947 to July 1, 1948
W. M. Hanley, Oct. 1, 1948 -

Purpose: to raise the grade of common lumber by resawing and gluing so that defects are mismatched in the two halves. Data will be obtained to determine the possibility of making joist and rafter grades from lumber that is, even at the present time, almost a waste product. Other studies in gluing involve the use of a radio-frequency generator in setting synthetic resin glues.

Project 16. Pyrolysis of Wood

Supervisor: Bror L. Grondal, Professor of Forestry

Research Fellow: Piotr Zenczak, Feb. 1, 1948 to Oct. 1, 1948

Purpose: to investigate Bergstrom's, Berle's, and Slavianski's various processes for the utilization of wood waste by pyrolysis or destructive distillation, and the possibility of applying these types of processes to the salvage of wood waste in sawmills in the state of Washington.

Project 17. Treatability of Western Hemlock

Supervisor: Bror L. Grondal, Professor of Forestry

Research Fellows: W. D. Page, April 1, 1948-
Ming Yu Koh, Oct. 1, 1948-

Purpose: to investigate the factors involved in the processing of western hemlock wood, with special reference to wood preservation. Because of the increasing scarcity of Douglas fir, western hemlock must be substituted for fir on a very wide scale. At present, hemlock cannot be dried satisfactorily by commercial processes; the object of this investigation is to obtain data that will correct this situation.

Project 18. Strength of Second-Growth Fir

Supervisors: Bror L. Grondal, Professor of Forestry
O. Harry Schrader, Jr., Associate Professor

Research Fellows: John W. Allen, Oct. 1, 1947 to July 1, 1948
W. G. Hughes, Oct. 1, 1947 to July 1, 1948
Paul T. Kennedy, Oct. 1, 1948 -

Purpose: to determine the strength of second-growth Douglas fir timbers and lumber obtained from trees in different site classes. No studies relating to the strength of such material have previously been made for use in designing structures where reasonably accurate data are necessary. The demand for this information is very insistent.

Project 19. Hardening of Wood

Supervisor: Bror L. Grondal, Professor of Forestry

Research Fellows: Ben S. Bryant, Oct. 1, 1947 to Aug. 1, 1948
Ralph S. Brindley, Oct. 1, 1948-

Purpose: to make an extended study of the hardening of softwood flooring through impregnation with synthetic resins. A method of such impregnation under pressure has been devised and may have excellent commercial possibilities.

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*A project undertaken by the University in cooperation with the Washington Toll Bridge Authority and the Public Roads Administration. Research fellows have been assigned by the Engineering Experiment Station to this project since 1945.

Project 20. Utilization of Laterite Deposits of the Pacific Northwest

Supervisor: Dr. R. W. Moulton, Associate Professor of Chemical Engineering

Research Fellow: J. S. Chittenden, Oct. 1, 1947 to April 1, 1948

Purpose: to study the application of the Pedersen Process for the recovery of alumina from high iron bauxites. Large reserves of this type of bauxite have been discovered in northwest Oregon. The possible recovery of titania at a cost low enough to compete with its production from other sources, is also to be studied.

Project 21. Processing of Olivine for the Recovery of Magnesium

Supervisor: Dr. R. W. Moulton, Associate Professor of Chemical Engineering

Technician: K. B. Bengtson, July 1, 1947 to Mar. 15, 1948

Research Fellow: H. H. Greenfield, Sept. 1, 1947 to July 1, 1948

Purpose: to determine conditions and design apparatus for economic conversion by the electrolytic process of the magnesium content of olivine to the chloride from which magnesium is produced. Washington has tens of millions of tons of the mineral, olivine, in two very extensive deposits which are not being used at the present time because the processing of the ore is exceedingly difficult by conventional methods of metallurgy.

Project 22. Gasification of Washington Coals and Utilization of the Resulting Gases

Supervisor: Dr. R. W. Moulton, Associate Professor of Chemical Engineering

Research Fellow: R. W. Evans, Aug. 1, 1947 to June 1, 1948

Supervisor: Dr. C. F. Gerald, Assistant Professor of Chemical Engineering

Research Fellow: B. J. Pope, Aug. 1, 1947-

Purpose: to find means of utilizing the extensive deposits of low grade Washington coals. Because of the lack of local supplies of crude oil, this program is concentrated on the production of liquid hydocarbons from CO and H_2.

Project 23. Lignin Utilization

Supervisor: Dr. J. L. McCarthy, Associate Professor of Chemical Engineering

Research Fellows: R. E. Davis, Oct. 1, 1947-
Eric Reaville, July 1, 1948-

Purpose: to find practical uses for the lignin in sulfite waste liquor and also in waste wood. The chemical structure of lignin is being studied. Attempts are being made to convert lignin into industrially useful low molecular weight substances by employment of hydrogenation and also by oxidation procedures. About one billion pounds of lignin per year are lost in the waste liquors from sulfite pulp mills.

Project 24. The Condensation of Formaldehyde with Phenols

Supervisors: Dr. J. L. McCarthy, Associate Professor of Chemical Engineering
Dr. R. W. Moulton, Associate Professor of Chemical Engineering

Research Fellow: F. C. Stults, Sept. 1, 1947-

Purpose: to secure additional and systematic information as to the rates of reaction of a number of different phenols with formaldehyde. Extensive use of the condensation products of phenol and formaldehyde is being made in the state of Washington, especially in the plywood industry, where the condensation products serve as a waterproof adhesive for the wood veneers.

Project 27. Design of Sulfur Dioxide Absorption Towers

Supervisors: Dr. J. L. McCarthy, Associate Professor of Chemical Engineering
Dr. F. S. West, Assistant Professor of Chemical Engineering

Research Fellow: D. A. Pearson, July 1, 1947 to Nov. 1, 1948

Purpose: to secure data which will permit a more accurate design of sulfur dioxide absorption towers than is available at present. Solutions of sulfur dioxide are often used in industry, particularly in the pulp and paper industries. Some equipment and materials for this research have been kindly supplied by the G. D. Jenssen Company, Inc. and by the Dow Chemical Company, Inc.

Project 28. Electronic Measurements and Controls

Supervisor: Andrew B. Jacobsen, Instructor in Electrical Engineering

Research Assistant: LeRoy D. Barter

Purpose: to assist the Engineering Experiment Station research groups in problems involving electronic measurements and controls by acting as consultants and performing work designed to meet their needs in this direction. At present a decrement commuter for Project 14 and an instantaneous water-level indicator for Project 7 are being designed and built.

Project 29. Electron Microscope

Oliver Rowe, Electron Microscopist

Purpose: to provide use and service of the Station's electron microscope for any department of the University requiring such service. Until the microscope of the Medical College is available for use, this microscope is the only one affording such service.

Project 30. Acoustics

Dr. R. W. Kenworthy Assistant Professor of Physics

Purpose: to determine the relation between the absorption coefficients of acoustical materials when measured under two different conditions: (1) in the laboratory with a small area of the material, and (2) in normal installations with a large area of the material.

Project 31. Stream Pollution

Supervisor: R. G. Tyler, Professor of Sanitary Engineering

Research Associate: William Maske

Research Fellow: W. W. Saxton, Oct. 1, 1947 to Aug. 1, 1948

Purpose: to work on problems dealing with the elimination and control of stream pollution; specifically, the determination of dissolved oxygen and the biochemical oxygen demand of strong industrial wastes such as sulfite waste liquor or wastes from canneries, tanneries, etc., which contain interfering substances that make the accurate determination of DO and BOD values difficult.

Project 32. Flow in Pipes and Channels

Supervisor: C. W. Harris, Professor of Civil Engineering

Research Associate: R. E. Shepard

Research Fellow: Roy Tinney, Oct. 1, 1947 to Aug. 1, 1948

Purpose: to carry on experiments that will add to the general knowledge of flow in pipes and channels and, specifically, (1) to establish a means of identifying pipe and channel surfaces in relation to their resistance to passage of water that will conform to modern concepts, and (2) to introduce a practical formula for applying a specific roughness coefficient, once found, to any size of pipe or channel.

Project 33. Viscosity of Oil Under Pressure

Supervisor: C. W. Harris, Professor of Civil Engineering

Research Fellow: Howard G. Anson, Oct. 1, 1947 to Aug. 1, 1948

Purpose: to obtain data concerning the effect of pressure on viscosity of oils not yet subjected to such tests, by the use of a rolling ball viscosimeter.

Project 34. Supersonic Wind Tunnels

Supervisor: G. E. Ledbetter, Research Associate in Aeronautical Engineering

Research Associate: D. W. Lueck

Research Fellow: J. H. Brown, Jan. 1, 1948-

Purpose: to design and construct two small supersonic wind tunnels with complementary instrumentation and to carry on studies in theory and design by means of this equipment.

Project 35. Hydrolysis of Cellulose

Supervisor: J. L. McCarthy, Associate Professor of Chemical Engineering

Research Fellow: Chung-Chao Shen, Oct. 1, 1947 to Nov. 1, 1948

Purpose: to investigate the rate of hydrolysis of cellulose under various conditions with the view of developing an economic process for production of glucose from waste wood.

Project 37. Hardness of Wood

Supervisor: Bror L. Grondal, Professor of Forest Products

Research Fellow: F. B. Baker, Jan. 1, to July 1, 1948

Purpose: to investigate the relationship of density, strength, and hardness of various woods, including a study of the relative hardness of the early and late wood in the annual growth rings of coniferous wood. A new type of testing machine to obtain these values has been constructed.

Project 38. The Heating of Non-Metallic Substances by the Use of High Frequency Electric Field*

Supervisor: Dr. R. W. Moulton, Associate Professor of Chemical Engineering

Research Fellow: H. Schuyten, Jan. 1, to Nov. 1, 1947
James Buckham, Jan. 1, to Oct. 1, 1948

Purpose: to find the rate of heating of various engineering materials in a high frequency field. The time-temperature distribution within the material being heated is being particularly investigated. This method of heating is applied in the setting of plywood glues and may be extended to other chemical industries.

Project 39. The Production of Powdered Iron by the Vapor-Phase Reduction of Iron Chloride

Supervisor: Dr. R. W. Moulton, Associate Professor of Chemical Engineering

Research Fellow: Richard Brooks, April 1, 1947 to Feb. 1, 1948

Purpose: to develop a process for producing high purity powdered iron by the vapor-phase reduction of iron chloride with hydrogen. The use of powdered iron and other powdered metals is increasing greatly. Small metal parts of accurate dimensions may be formed from powdered metals at low cost.

Project 40. Cosmic Ray Apparatus

Supervisor: J. E. Henderson, Professor of Physics

Research Fellow: E. C. Stewart, July 1, 1947 to May 1, 1948

Purpose: to design and test electronic coincidence circuits to be used in connection with Geiger counters which trip Wilson cloud-expansion chambers immersed in an intense magnetic field. The tracks of the cosmic ray particles are photographed in the chambers and later studied.

Project 41. Determination of Electric Strain Gage Characteristics at Varying Temperatures

Supervisor: E. E. Day, Assistant Professor of Mechanical Engineering

Research Fellow: Ling-wen Hu, Oct. 1, 1948-

Purpose: to determine how the characteristics of commercial gages vary when subjected to extreme temperature conditions. Industrial applications have increasingly been demanding use of these gages at higher and higher temperatures without enough investigation of the effects such temperatures have on the gage itself.

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*Conducted in co-operation with the Department of Electrical Engineering.

Project 42. Cement-Aggregate Reactions*

Supervisor: H. A. Coombs, Associate Professor of Geology

Research Fellow: H. W. Smedes, May 1, 1948-

Purpose: to study the effects of high-alkaline cements and their reaction on the aggregate in the making of concrete. Some aggregates react with high-alkaline cement and produce excessive expansion effects.

Project 43. Sewage Disposal

Richard G. Tyler, Professor of Civil Engineering

William Maske, Research Associate

Purpose: to investigate the extent and concentration of the sewage field at the principal Seattle sewer outlets into Puget Sound. This project was carried on in co-operation with the State Stream Pollution Control Commission, the State Health Department, and the City Health Department of the City Engineer's office. Aerial photographs have been made by Navy planes to show the course of the dyes used as tracer materials.

Project 44. Chemical Reactions Under the Influence of of Dielectric Heating* *

Supervisor: Dr. R. W. Moulton, Associate Professor of Chemical Engineering

Research Fellows: H. Schuyten, Jan. 1 to Nov. 1, 1947

James A. Buckham, Jan. 1, to Oct. 1, 1948

Purpose: to continue research started under Project 38 with special emphasis on the effect of high-frequency heating on chemical reactions.

Project 45. Liquid-Liquid Extraction

Supervisor: Dr. R. W. Moulton, Associate Professor of Chemical Engineering

Research Fellow: Albert L. Purvis, April 1, 1948-

Purpose: to study the effectiveness of various types of liquid-liquid extraction units. This type of equipment is used for the recovery of valuable by-products and solvents in chemical processing plants. Different tower-packing materials will be tested and packed towers will be compared with mechanical contactors.

Project 46. Electrolytic Conversion of Glucose

Supervisor: Dr. J. L. McCarthy, Associate Professor of Chemical Engineering

Research Fellow: George Szego, April 1 to Oct. 1, 1948

Purpose: to investigate the electrolytic conversion of glucose (which is potentially available in huge amounts from wood and other plants) to lower molecular weight molecules. Preparation of formaldehyde, useful in the Pacific Northwest plastics and plywood adhesives industries, is of particular interest.

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*In co-operation with the Department of Civil Engineering.

**In co-operation with the Department of Electrical Engineering.

Project 47. Photoelastic and Analytical Stress Analysis of a Turbine Rotor Subjected to Normal Loading

Supervisor: E. E. Day, Assistant Professor of Mechanical Engineering

W. B. Nordquist, Instructor in Mechanical Engineering

Purpose: to investigate stresses in a turbine rotor analytically and then check by means of three-dimensional photoelastic techniques. With increasing emphasis on military and commercial use of turbines, it is essential that stress conditions set up in them be determined as accurately as possible.

Project 48. Preservation of Old Piles*

Warren Philbrick, Research Associate

Purpose: to find an economical and effective means of coating, wrapping, or encasing piles, which will kill any existing infestation and prevent further attack by marine life.

Project 50. Experimental Study of the Stresses and Deflections in Swept Triangular Plates

Supervisor: V. J. Martin, Associate Professor of Aeronautical Engineering

Research Fellows: W. L. McLaughlin, Oct. 1, 1948-

Henry C. Cheng, Oct. 1, 1948-

Purpose: to conduct an experimental investigation of the stresses and deflections in swept triangular plates. It is hoped that such data will help in setting up a theoretical approach to this difficult problem. Such plates are used as fins on missiles and are a first approximation to swept wings.

Project 51. Behavior of Elastic Beams Under Shock Loads

Supervisor: R. M. Rosenberg, Associate Professor of Aeronautical Engineering

Research Fellow: R. J. Doty, Oct. 1, 1948-

Purpose: to determine experimentally the accelerations along an elastic beam when the accelerations are caused by shock loads. The theory which is being developed at present is a radical departure from the approach used heretofore and provides greater accuracy of results. Its application in aeronautics is the effect of landing impacts in aircraft structural components.

Project 52. Experimental Check on a New Theory for the Design of Metering Pins in Oleo Struts

Supervisor: R. M. Rosenberg, Associate Professor of Aeronautical Engineering

Research Fellow: H. P. Durand, Oct. 1, 1948-

Purpose: to check experimentally a new theory which has been developed for the design of metering pins in aircraft oleo struts. Heretofore such designs have been trial and error processes which are both time consuming and expensive. The same theory is applicable to the design of flying-boat hulls.

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*In co-operation with the Fisher Flouring Mills.

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BULLETINS

48. The Influence of Pipe Thickness on Re-Entrant Intake Losses. Charles William Harris. 35 pp. 1928.
55. Vacuum-Tube Control for Electric Wind-Tunnel Balances. Fred Scoville Eastman. 20 pp. 1931.
56. Constant Flow Characteristic of the Plane Orifice in Proximity to Side Walls. Charles William Harris. 18 pp. 1931.
58. Preliminary Tests of Thirteen Washington Coals in a Powdered Coal Boiler Plant at the University of Washington. George Samuel Wilson, Harry Fagan Yancey, and Joseph Daniels. 27 pp. 1931.
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61. Hydraulic Flow Characteristics of a Square-Edged Intake. Charles William Harris. 21 pp. 1932.
67. The Doherty Washer Cooler. Sybren Ruurd Tymstra. 61 pp. 1932.
72. The Derivation of the Mean Temperature Difference Between a Saturated Gas and a Cooling Liquid, and also the Derivation of the Mean Velocity of Such Gas. Sybren Ruurd Tymstra. 19 pp. 1933.
73. The Production of Sodium Nitrite from Arced Nitrogen. Edgar Allen Loew and Warren Lord Beuschlein. 54 pp. 1933.
74. The Deformation of Hard Grade Reinforcing Steel During and After Construction in a Reinforced Concrete Building. Sergius Ivan Sergev. 33 pp. 1933.
75. The Water Tube Gas Condenser. Sybren Ruurd Tymstra. 24 pp. 1934.
76. Kaolin and China Clay in the Pacific Northwest. Hewitt Wilson. 184 pp. 1934.
77. A Study of Fundamental Relations of the Mathematical Theory of Elasticity. Arthur Melvin Winslow. 25 pp. 1934.
78. Hydroelectric Power in Washington. Part III, A Brief on Proposed Grand Coulee Dams. Carl Edward Magnusson. 32 pp. 1935.
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95. Hydroelectric Power in Washington. Part V, A Bibliography of Technical Papers. 1926-1935. Carl Edward Magnusson. 204 pp. 1937.
96. Hydroelectric Power in Washington. Part VI, International Boundary Waters. Carl Edward Magnusson. 17 pp. 1937.
97. Strength of Concrete for Mixes of Various Proportions. Ira Leonard Collier. 28 pp. 1938.
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114. The Effect of Shearing Forces on the Deflection and Strength of Beams. Sergius I. Sergev. 20 pp. 1947.

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2. Iron and Steel Manufacture in Washington, Oregon, California and Utah. Joseph Daniels. 69 pp. 1929.
3. Coal in Washington. Joseph Daniels. 17 pp. 1934.
4. Water Resources of Washington. Richard Gaines Tyler. 61 pp. 1938.
5. The Terminal Plan: An Improved System of Urban Transportation. Austin Vitruvius Eastman. 64 pp. 1938.
6. Aerodynamic Stability of Suspension Bridges with Special Reference to the Tacoma Narrows Bridge. Part I, Investigations Prior to October, 1941. F. B. Farquharson. (In press.)
7. Aerodynamic Stability of Suspension Bridges with Special Reference to the Tacoma Narrows Bridge. Part II, Mathematical Analyses. F. C. Smith and G. S. Vincent. (In press.)

TECHNICAL NOTES

2. The Modulus of Elasticity of the High Strength Concrete Used in the Ross Dam. F. C. Smith. 16 pp. 1940.
3. The Theory of Fractional Parts Developed for Structural Beam-column Members Preceded by an Elementary Discussion of Simple Beam and Column Design. Sybren Ruurd Tymstra. 32 pp. 1943.
4. Gaging Chart for Horizontal Cylindrical Tanks with Flat Heads or with Convex Heads. Sybren Ruurd Tymstra. 4 pp. 1944.
5. Gaging Chart for Cylindrical Tanks with Different Types of Heads. Sybren Ruurd Tymstra. 7 pp. 1945.
6. The Heat Pump for Residential Heating. G. S. Smith, H. Christensen, and A. Presson. 23 pp. 1948.